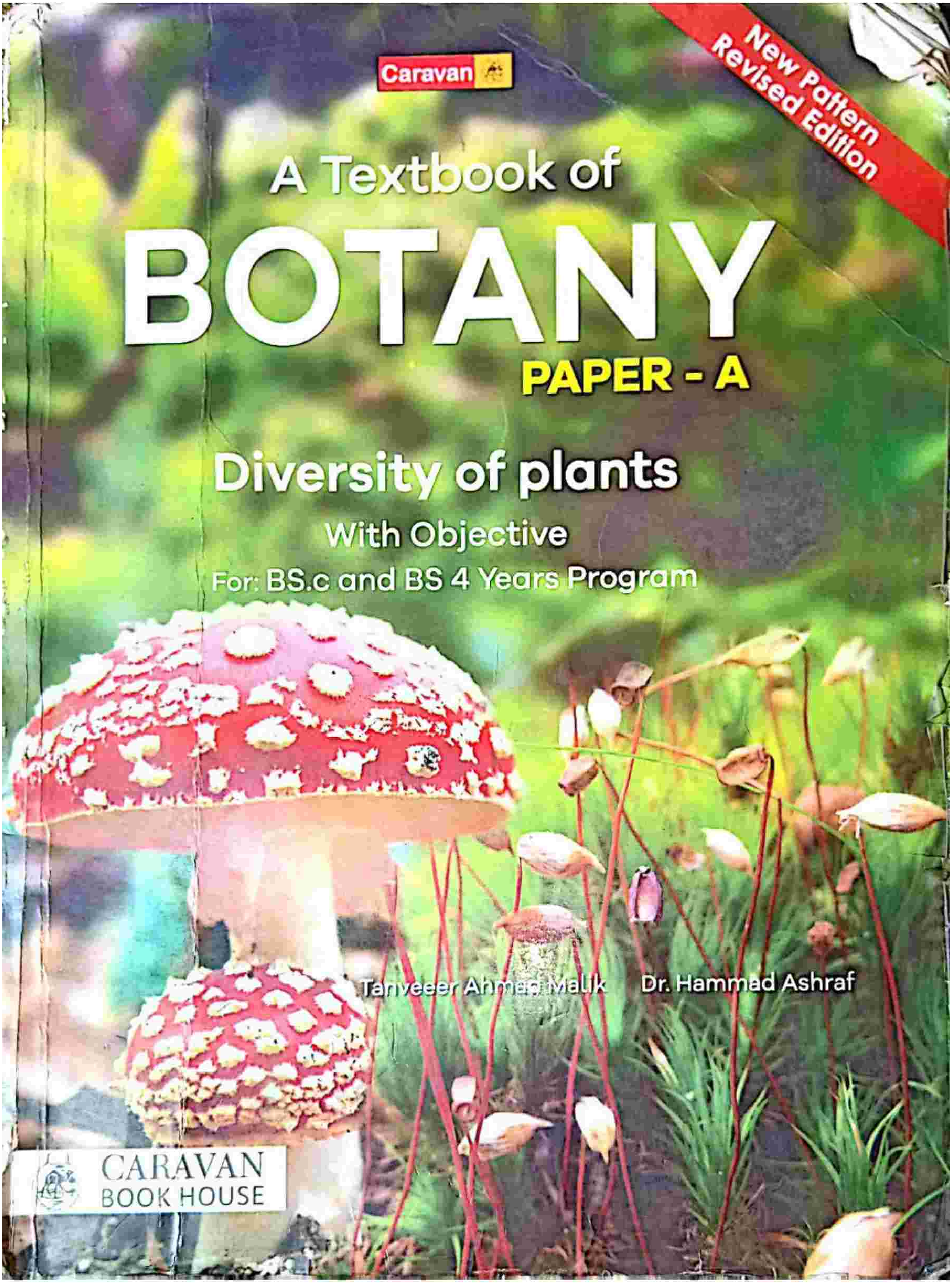

Caravan

New Pattern
Revised Edition

A Textbook of
BOTANY
PAPER - A

Diversity of plants

With Objective
For: BS.c and BS 4 Years Program

Tanveeer Ahmad Malik Dr. Hammad Ashraf

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Textbook of BOTANY

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Paper A

Nazim Raza.

for B.Sc & BS (4 Year) Classes

DIVERSITY OF PLANTS

([illegible] Raza)

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CONTENTS

Section I: PLANT DIVERSITY 1
An Out Line of Classification 3

Section II: THE VIRUSES 11
History of Discovery of Viruses 13
Types and Morphology of Viruses 14
Bacteriophage 18
Life Cycle of Bacteriophage 20
Tobacco Mosaic Virus (RNA & DNA) 23

Section III: THE BACTERIA 25
Morphology of Bacteria 27
Structure of Bacterial cell 29
Growth in Bacteria 32
Reproduction 33
Nutrition in Bacteria 40
Biological Importance of Bacteria 43

Section IV: CYANOBACTERIA 49
General characters of cyanobacteria 51
P Nostoc P 55
Anabaena P 58
Oscillatoria P 61

Section V: THE ALGAE 65
General Characters 67
Classification of Algae 77
Economic Importance of Algae 82
Chlorophyta: General Characters 86
Chlamydomonas 87
Volvox 91
Spirogyra 96
Charophyta General Charcters 100
① Chara 101
Xanthophyta General Characters 110
Vacucheria 111
Bacillarophyta General charcters (Diatom) 116
Pinnularia 119
Phaeophyta General Charcters (Brown algae) 123
④ Ectocarpous [illegible] Brown algae (marin) 124

Laminaria 128
Rhodophyta ✓ 133
Batracospermum 135
② * Polysiphonia ... R.c.p:→ Remaining) 141

Section VI: THE FUNGI 147
General Characters 149
Mode of Nutrition 154
Reproduction 156
Life Cycle 159
Economic Importance of Fungi 160
Classification of Fungi 164
Myxomycota 168
Plasmodiophora 169
Mastigomycotina 171
Pythium ... All → (Fungi) 172
* Mucor ... + crop implimentation and industrial applications 175
Ascomycotina 179
Fruiting Bodies of Ascomycetes 182
Saccharomyces 184
* Penicillium ✓ P 188
* Phyllactinia 192
Basidiomycotina 196
* Ustilago 200
* Pucinia Graminis ✓ 205
* Agaricus ✓✓ P 209
Deuteromycotina 216
Alternaria 217
* Lichens only physical) 219
Physcia 227

Section VII: THE BRYOPHYTA 233
General Characters 235
Classification of bryophyte 241
(Hepatophyta) 243
① * Riccia P 244
Porella 251
(Anthocerophyta) 256
④ * Anthocerous 257
Bryopsida 265
③ ⑤ Funaria 266
Polytrichum 273

Section VIII: INTRODUCTION TO VASCULAR PLANT **281**
Organization of Vascular Plant Body 283
Nature of Vascular Plant 284
Fossil Record and Geological time scale 289
Pteridophytes 297
General Characters 299
Classification of Pteridophytes ✓ 307
Psilophyts 308
① Psilotum 309
Microphyllophyte 320
② Selaginella 322
③ Equisetum 337
④ Pteropsida (marsilea) 348
Adiantum 349
Polypodium 360
✓ Marselia 365

Section IX: GYMNOSPERMS **379**
General Characters 381
Affinities of Gymnosperms 387
Classification of Gymnosperms 389
Cycadophyta 391
① Cycas 392
Coniferales ② Pinus = ? 407
Gnetophyta 422
③ Ephedra 423

Section X: ANGIOSPERMS **437**
Angiosperm Plant Body 439
Gametophyte .... Monocot (poaceae) 441
The Embryo .... ✓ [Dicote (solanacae) 442

✓ **Section XI: COMPARISON AMONG GROUPS** **447**

✓ **FILL IN THE BLANKS** **457**

✓ **TRUE FALSE** **495**

✓ **MULTIPLE CHOICE QUESTIONS** **525**

SECTION I

PLANT DIVERSITY

PLANT DIVERSITY

Plant diversity refers to the variety of plants that exist in the world.

Plants compete with other plants and organisms to survive in an ecosystem. Over time, they develop various characteristics to help them survive, which leads to plant diversity. Plant diversity is important because various species come to depend on each other; therefore, eliminating one species can cause several other species to suffer.

AN OUTLINE OF CLASSIFICATION

Microorganisms and Plants

An outline of Classification of living organisms as under:

Viruses

Viruses cannot be fitted into a classification of living things because they are not cellular. Viruses consist of a strand of nucleic acid and a protein coat. They are classified separately according to their chemical and physical properties.

Super-kingdoms —Prokaryota and Eukaryota

All cellular organisms so far studied fall naturally into one of two major groups, the prokaryota and eukaryota.

The prokaryotes appeared about 3500 million years ago and comprise a variety of organisms collectively known as bacteria. The cells of prokaryotes (pro=before + karyon=nucleus) lack true nuclei. In other words, their genetic material (DNA) is not enclosed by nuclear membranes, and lies free in the cytoplasm.

Eukaryotes include protoctista, fungi, green plants and animals. They appeared first in the late pre-Cambrian period, about 2000 million years ago, and probably evolved from prokaryotes. The cells of eukaryotes (eu=true) are much more complex and are characterized by a true nucleus, i. e., genetic material is enclosed by nuclear envelope to form a definite, easily recognizable structure.

SUPER KINGDOM:PROKARYOTA

Kingdom:Monera

The kingdom exhibits following general characteristics.

i. The genetic material is circular DNA, occurring naked in the cytoplasm, and normally attached to the cell membrane.

ii. The cytoplasm contains few organelle, and none are surrounded by a two-membrane envelope. Ribosomes are present, but are small as compared with eukaryotes.

iii. The cell wall is a rigid structure made of polysaccharides with amino acid residues combined in it.

iv. Some organisms have the ability to fix atmospheric nitrogen into organic compounds (amino acids).

The kingdom contains all bacteria and cyanobacteria and can be broadly classified into two phyla: the cyanobacteria and bacteria.

i.Phylum:Cyanobacteria

The phylum includes spherical or rod-shaped unicellular organisms (*Chroococcus*), or simple or branched filamentous prokaryotes (*Oscillatoria*, *Nostoc*, *Anabaena*) They exhibit following general characteristics:

i. They are photosynthetic with photosynthetic pigments held in plasma membranes around the periphery of the cells.

ii. The photosynthetic pigments are chlorophyll (green), phycoerythrin (red) and phycocyanin (blue). The blue pigment is dominant.

iii. Certain species of cyanobacteria live mutualistically with fungi forming lichens.

iv. Many species contain gas vacuoles, and the cells float at the surface of the water in which they live.

ii.Phylum:Bacteria

The phylum includes bacteria, the smallest cellular organism

Bacteria exhibit following general characteristics.

i. They are unicellular prokaryotes, but the cells often remain attached after division, forming clumps, chains or simple filaments. They are about 1 um in diameter and range between 0.1-10 um in length.

ii. The nutrition is varied: many bacteria are heterotrophs and absorb externally digested food, others are autotrophs and get nutrition either by chemosynthesis or photosynthesis.

iii. Many bacteria cause decay and, with fungi, facilitate recycling of nutrients.

iv. Certain bacteria are parasites on other organisms and cause specific diseases such as food poisoning in animals, and soft rots of various vegetable plants.

v. Bacteriologists divide the bacteria into several phyla on the basis of differences in metabolism and cell structure.

Escherichia coli, a rod-shaped bacterium, serve as typical bacterium for detailed studies.

SUPER-KINGDOM: EUKARYOTA

1.Kingdom: Protoctista

Protoctista contains eukaryotes that are generally regarded as identical and similar to the ancestors of modern plants, animals and fungi. The Protoctista include two sub-kingdoms: the Protozoa and Algae. Both sub-kingdoms formerly had taxonomic status. The algae were classified alongwith fungi in the division: Thallophyta and protozoans as phylum: Protozoa in invertebrates. These two diverse groups are placed together on the basis of a relatively simple level of organization.

i.Sub-Kingdom: Algae

The sub-kingdom includes oxygen-producing photosynthetic eukaryotic organisms with a cell structure similar to that of green plants. Algae show great diversity in structure, ranging from unicellular (*Chlamydomonas*) and simple filamentous

(*Spirogyra*) to huge seaweeds (*Fucus*). Algae occur in water or on very damp surfaces. Their bodies lack true stems, roots and leaves, i. e, a thallus. Algae are classified into distinct phyla on the basis of their photosynthetic pigments.

a.Phylum: Chlorophyta (green algae)

The green algae is very similar to green plants in cell structure and biochemistry. Chloroplasts contain the pigments chlorophylls a and b, carotene and xanthophyll. The dominant pigment is chlorophyll. Starch is the stored food. The cell walls are made of cellulose. Plant body is single-celled (*Chlamydomonas*), or a filament (*Spirogyra*), or a colonial form (*Volvox*), or shaped as flattened thallus, i. e., thalloid (*Ulva*). Most green algae are found in freshwater.

b.Phylum:Bacillariophyta (diatoms)

Diatoms have unusual wall made from celluloses and impregnated with silica. The walls consist of two halves called valves, which fit together like the halves of a petri dish. Chloroplasts contain pigments chlorophylls a and c, carotene and the xanthophyll fucoxanthin. Oil is stored as food reserve. The example are*Pinnularia*.

c.Phylum: Xanthophyta (yellow-green algae)

The members of this division are characterized by their yellow-green colour due to dominance of xanthophyll diadinoxanthin. The cell wall consists of two overlapping halves. The reserve food is oil drops. The most commonly occurring genus is *Vaucheria.*

d.Phylum: Phaeophyta (brown algae)

Nearly all brown algae is marine found in intertidal zone of a rocky shore. There are only three freshwater genera. The plant body is a multicellular thallus with a degree of tissue differentiation, however water-conducting cells have not evolved. Chloroplasts contain the pigments chlorophylls a and c with carotene and fucoxanthin— a brown pigment that dominates the others. The food reserves include a carbohydrate, laminarin starch. Reproduction is sexual, and many species have haploid and diploid alternation of generations. They are commonly called seaweeds, for example *Fucus*.

e.Phylum: Rhodophyta (red algae)

The red algae are marine plants of the lower part of the intertidal zone. Chloroplasts contain chlorophyll a, carotene and xanthophyll pigments. But the dominant pigment is red phycobilin. The plant body is composed of branched filaments or aggregations of filaments. The life cycles of red algae are complex, usually with alternation of generations. The examples are *Batrachospermum* and *Polysiphonia*.

II. Phylum: Oomycota

This phylum was originally classified with fungi but now included in Protoctista. The plant body consists of hyphae which have not cross-walls, i. e., non-septate. The cell walls contain cellulose. Asexual reproduction is by means of biflagellate zoospores produced in sporangia. The sexual reproduction is by oogamy, involving fusion of an oosphere (female gamete) with a male gamete to produce an oospore. The phylum includes disease causing agents, for example *Phytophthorainfestans* that causes potato blight disease, and *Pythium*— a parasite that causes damping-off of seedlings.

2.Kingdom: Fungi

The fungi are a large and successful group of organisms of about 80,000 named species. They range in size from the unicellular yeasts to the large toadstools, puffballs and stinkhorns, and occupy a very wide range of habitats. Fungi are eukaryotic organisms with protective walls composed of chitin. The plant body is a mycelium consisting of thread-like hyphae. The hyphae may be divided by septa (cross walls) into short, multinucleate section. The fungi lack chlorophyll and their nutrition is non-photosynthetic. Some feed as parasites, others are mutualistic, but most are saprotrophic – absorptive, secreting enzymes on to food and absorbing the products of external digestion. The reserve food, if present, is glycogen. Most fungi are known to reproduce sexually and asexually. The gametes and spores produced are without flagella.

The kingdom Fungi is further classified into:

i.Phylum: Zygomycota (zygomycetes—moulds)

The phylum includes saprotrophic fungi widespread in soils, dung, and common in decaying food. The mycelium is branched and composed of non-septate hyphae. Asexual reproduction is by conidia or sporangia containing spores. Sexual reproduction is by conjugation, involving fusion of two gametangia to produce a resistant zygospore. The examples are*Rhizopusstolonifer*.

ii.Phylum: Ascomycota (ascomycetes— the sac fungi)

The yeasts (Saccharomyces), cup-fungi (*Peziza*), *Penicillium,* and powdery mildews (*Phyllactinia*) are included in this phylum. The plant body or mycelium is composed of septate, multinucleate hyphae. Asexual reproduction is by conidia. Sexual reproduction involves production of specialized sexual spores, the ascospores produced inside a special structure, the ascus. In most species there is a cup-shaped or flask-shaped fruiting body in which the asci are formed.

iii.Phylum: Basidiomycota (basidiomycete— club fungi)

The phylum include mushrooms (*Agaricus*), rusts (*Puccinia*), smuts (*Albugo*), toadstools, puffballs and bracket fungi. The organisms are composed of septate hyphae. Asexual reproduction is by formation of spores but not very common. Sexual reproduction involves production of special sexual spores, the basidiospores, occurring on the club-shaped tip of a special hypha, the basidium.

iv.Phylum: Deuteromycota (fungi imperfecti)

The phylum include fungi in which sexual reproduction has never been observed, and whose classification is uncertain, for example *Alternaria*.

v.Phylum: Mycophycophyta (lichens)

The phylum contains lichens. Lichens are dual organisms, formed by an association between an alga (green alga or cyanobacterium) and a fungus (usually an ascomycete). The lichen thallus consists of compact fungal hyphae surrounding algal cells and taking the form of an encrusting (crustose), a leaf-like thallus (foliose) or a tiny shrub (fruticose). Each component is dependent upon the other; the algal cell manufacture sugar, and the fungi retain ions as and when they become available.The examples are *Physcia* and *Cladonia*.

3.Kingdom: Plantae (green plants)

The green plants are multicellular eukaryotes with cell walls containing cellulose and other polysaccharides. They are autotrophic and the majority are photosynthetic Photosynthesis occurs in chloroplasts which contain the pigments chlorophylls a and b, xanthophyll and carotene. The life histories of green plants involve two generations which alternate with each other. First, a diploid generation occurs, known as sporophyte, during which spores are formed. This is followed by a haploid generation, called gametophyte, during which sex cells or gametes are produced.

The International Code of Botanical Nomenclature recommends that each major group of the plant kingdom should be called a division.

i.Division: Bryophyta

Bryophytes are the first plants to colonize the land and are generally thought to have evolved from green algae. It is the simplest group of land plants evolved about 420 million years ago. They exhibit alternation of generations during which the gametophyte is the conspicuous and dominant generation. The sporophyte is attached to and dependent upon the gametophyte for its function. Bryophytes are largely restricted to moist environments. They lack true roots and the plants are anchored by thin filamentous outgrowths, the rhizoids. The water-conducting (xylem) and elaborated food-conducting (phloem) tissue are absent. Bryophytes have evolved antheridia (male reproductive organs) and archegonia (female reproductive organs) but they require water for transport of male gamete to female gamete. Asexual reproduction is by spore formation. The spores are produced in specialized spore-producing structures, the capsule.

a.Class:Hepaticeae (liverworts)

Liverworts either have a flat thallus (*Marchantia, Riccia, Pellia*) or a stem (Lophocolea) with three ranks of leaves. These are anchored by unicellular rhizoids. Spores are produced in capsule. The wall of the capsule splits into four valves for spore dispersal. The elators aid in dispersal of spores.

b.Class: Musci (mosses)

Mosses are small, leafy structures with spirally arranged leaves, and anchored by multicellular rhizoids. The capsule of the sporophyte has an elaborate mechanism of spore-dispersal, dependent on dry conditions and involving teeth or pores. The elators are absent. Common examples of mosses are Funaria and Sphagnum — a bog-moss.

Tracheophytes

The remaining groups of kingdom plantae are collectively known as tracheophytes. Tracheophytes have a conspicuous and dominant sporophyte generation in the form of a plant differentiated into stem, leaf and root. Vascular tissue (xylem and phloem) is present. It is composed of lignified cel mostly. All the vascular plants were formerly included in one division, the Tracheophyta with club mosses, horsetails and ferns, and the more advanced groups, the seed-bearing plants (gymnosperms and angiosperms), being classified as sub-divisions.

ii.Division: Lycopodophyta (club mosses)

- The division includes plants with small, spirally arranged leaves. The leaves are microphyllous, i. e., have a single mid-vein. The sporangia are usually produced in cones or strobili. The sporangia are produced on the dorsal surfaces of leaves called sporophylls. Some club mosses are homosporous (*Lycopodium*) while others are heterosporous (*Selaginella, Marselia*). Heterospory is regarded as first step towards seed formation. The gametophyte is independent but smaller and inconspicuous usually called a prothallus.

iii.Division: Sphenophyta (horsetails)

The horsetails possess microphyllous leaves arranged in whorls around the stem. The sporangia are produced in cones on distinctive sporangiophores. The plants are homosporous. The only surviving genus is *Equisetum*.

iv.Division: Filicinophyta (ferns)

The leaves in ferns are macrophyllous, i. e., large and have branching veins, and called fronds. These are tightly coiled and uncoil in early growth and development. The sporangia develop on lower surface of the leaves in clusters called sori. Each sorus contains many stalked sporangia. The ferns are homosporous. The examples are *Dryopteris, Pteridium, Adiantum and Marselia*.

Seed Plants

The gymnosperms (conifers) and angiosperms (flowering plants) are characterized by formation of seeds, therefore called seed plants. The sporophyte is the dominant generation; gametophyte is very much reduced. The plants are heterosporous, i. e., produce two types of spores, the microspores and megaspores. The megaspore is retained in the megasporangium (ovule), and a fertilized ovule is a seed. Both groups do not need water for fertilization, they convey sperms to the ovum by a pollen tube.

v.Division: Cycadophyta

The division includes both extinct and extant gymnospermous seed plants with fern-like leaves. The cycads are also called living fossils because of their resemblances to extinct seed ferns. The male cones of cycads are largest among the gymnosperms. The sporangia are produced in sori. The common examples are *Cycas, Zamia, Microcycas, Dioon*, etc.

vi.Division: Coniferophyta (conifers)

The division includes cone-producing plants in which the seeds are naked, i. e., not enclosed in a fruit. Leaves are usually waxy and needle-shaped. The sporangia and spores develop in cones. Male and female cones are separate but develop on the same plant. The vessels are absent in xylem tissue and phloem contains albuminous cells similar in function to companion cells, but different in origin. The common examples are *Pinus, Cedrus*.

vii.Division: Gnetopsida

The members of the division are xerophytic small shrubby trees. The male and female cone are compound structures and usually referred to as flowers. The ovules are surrounded by many envelopes regarded as extra integuments. The micropylar tube is extremely elongated and forms a bristle-like tube. The secondary wood contains vessels. The common genera are *Ephedra* etc.

viii.Division: Angiospermatophyta (flowering plants)

The angiosperms are dominant group of land plants. They are seed-bearing plants, with the seed enclosed in fruits formed from the ovary. Xylem contains vessels and phloem contains companion cells. The flowers are unique to angiosperms. The sporangia and spores develop in the flowers. The development of flowers has been associated with the evolution of complex mechanisms for pollen transfer (pollination) and seed dispersal, sometimes involving insects, birds and mammals, and the agency of wind and water.

Angiospermatophyta includes two classes.

a.Class: Monocotyledoneae (monocots)

The leaves of monocots mostly have parallel veins. The embryo plant in the seed has a single cotyledon (seed-leaf). The vascular bundles are scattered. Vascular cambium is usually absent and there is no secondary growth. Floral parts are usually in threes or multiples of threes. Perianth is not distinguished into calyx and corolla. Usually wind pollinated. The examples are *Poa* (an annual meadow grass), *Triticum* (wheat), iris, lilies, orchids.

b.Class: Dicotyledoneae (dicots)

The leaves in dicots have net veins. The embryo plant in the seed has two cotyledons (seed-leaves). The vascular bundles are arranged in a ring. Vascular cambium is usually present giving rise to secondary growth. Floral parts are in fours or fives or multiples of fours and fives. Usually insect pollinated. The examples are *Ranunculus* (buttercup), *Quercus* (oak tree), *Rosa* (rose) and *Lathyrus* (pea).

⟷

SECTION II

THE VIRUSES

Chapter 1

THE VIRUSES

Viruses

It can be defined as non-cellular infectious entities which contain RNA or DNA encased in protein coat and reproduce only in living cell.

HISTORY OF DISCOVERY OF VIRUSES

The word VIRUS is derived from latin word venome means poisonous substance, was used to describe any disease-causing substance.

About 50 years before development of the electron microscope, the existence of viruses was demonstrated as a large group of acellular disease-causing agents composed of nucleic acid encapsulated in a protein coat, by L. Pasteur in 1884 and A. Mayer in 1886 during their studies on mosaic disease of tobacco plants. They exhibited that the disease can be transmitted from one host to another under controlled laboratory conditions. However, the nature of viruses was not clearly established by their experiments because neither of these viruses could be grown in pure culture by the methods available at that time.

In 1892, D. Iwanowsky prepared an extract from tobacco plants that were suffering from mosaic disease. When the extract was passed through a filterable to prevent the passage of bacteria, the filtrate was able to infect healthy tobacco leaves. As a result of this experiment, these disease-causing agents were named filterable viruses.

In 1898 M. Beijernickestablished that viruses possess the property of replication that is common to all living things. He further established that these disease-causing filterable viruses multiply in the host cells.

Later F. Twort and F. d'Herelle independently discovered that some viruses infect bacteria. They termed these viruses bacteriophages, i. e., eaters of bacteria, or simply phages. This discovery established the fact that viruses infect and cause diseases in all the three major biological groups, the animals, plants and bacteria.

In 1935, W. Stanley demonstrated the structure of plant virus TMV. He crystallized the virus and then showed that it is largely composed of protein. Later, other scientists showed that these crystals also contain a small but constant amount of RNA. Chemical studies of other viruses revealed that some contain DNA in addition to protein, but no virus has been found to contain both DNA and RNA. In addition to nucleic acid, some viruses contain lipid, and some contain small amounts of carbohydrates conjugated to their protein components. The largest and most complex viruses, the poxviruses, are composed of nucleic acid and several internal compartments surrounded by membranes.

CHARACTERISTICS OF VIRUSES

The chief characteristics of viruses are:

i. They are disease causing agent.

ii. They are quite small, therefore invisible in the light microscope and able to pass through filters that retain most bacteria.

iii. They do not multiply in cultures designed to support growth of bacteria, i. e., they are non-living outside the host cells.

iv. They are composed of nucleic acid DNA or RNA core surrounded and protected by a protein coat called capsid.

v. The DNA or RNA functions as viral genome. Those that contain RNA contain an unusual biological property of having genetic information permanently encoded in RNA.

TYPES OF VIRUSES

Generally the viruses can be divided into the following types:

i. Animal Viruses:

These cause diseases in man and other animals. They usually consist of DNA core protected by capsid.

ii. Plant Viruses:

These cause diseases in plants. A plant virus consists of RNA core surrounded by protective protein coat. For example tobacco mosaic virus (TMV).

iii. Retroviruses:

This is a special group of viruses. They have RNA as their genetic material. They cause serious disease such as AIDS in humans.

iv. Geminiviruses:

These are plant viruses that contain single-stranded DNA as genetic material.

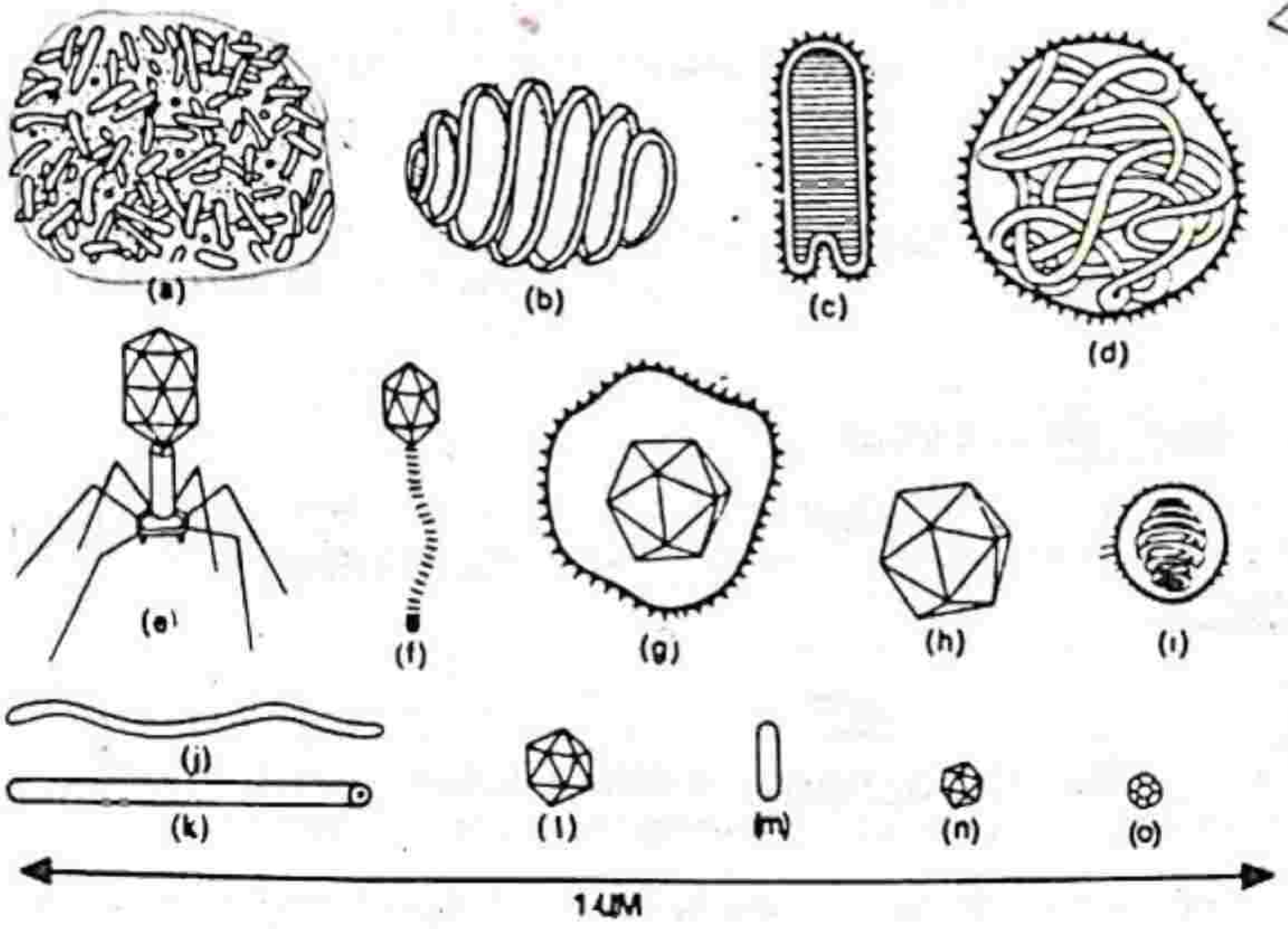
MORPHOLOGY OF VIRUSES

Size and Shape of Viruses

Viruses vary greatly in size and shape. The smallest, simplest and structurally complete infectious viruses are virions.

Size

These range in size from 20 to 350 nm. Most viruses range in size between 10 and 300 nanometers. Poliomyelitis, yellow-fever and foot-and-mouth disease-causing viruses are smaller in size with a diameter of about 25 nm, whereas smallpox viruses are larger, about 250 nm in diameter. Since most viruses measure less than 150 nm, therefore they are visible only under electron microscope.



P

(a,b) *Poxviruses*, (c) *Rhabdo virus*, (d) *Mumps virus*, (e) *T-even phage*, (f) *Potato virus*, (g) *Herpes virus*, (h) *Adeno virus*, (i) *Influenza virus*, (j) *Potato virus X*, (k) *Tobacco mosaic virus*, ((l) *Papilloma virus*, (m) *Alfalfa mosaic virus*, (n) *Polio virus*.

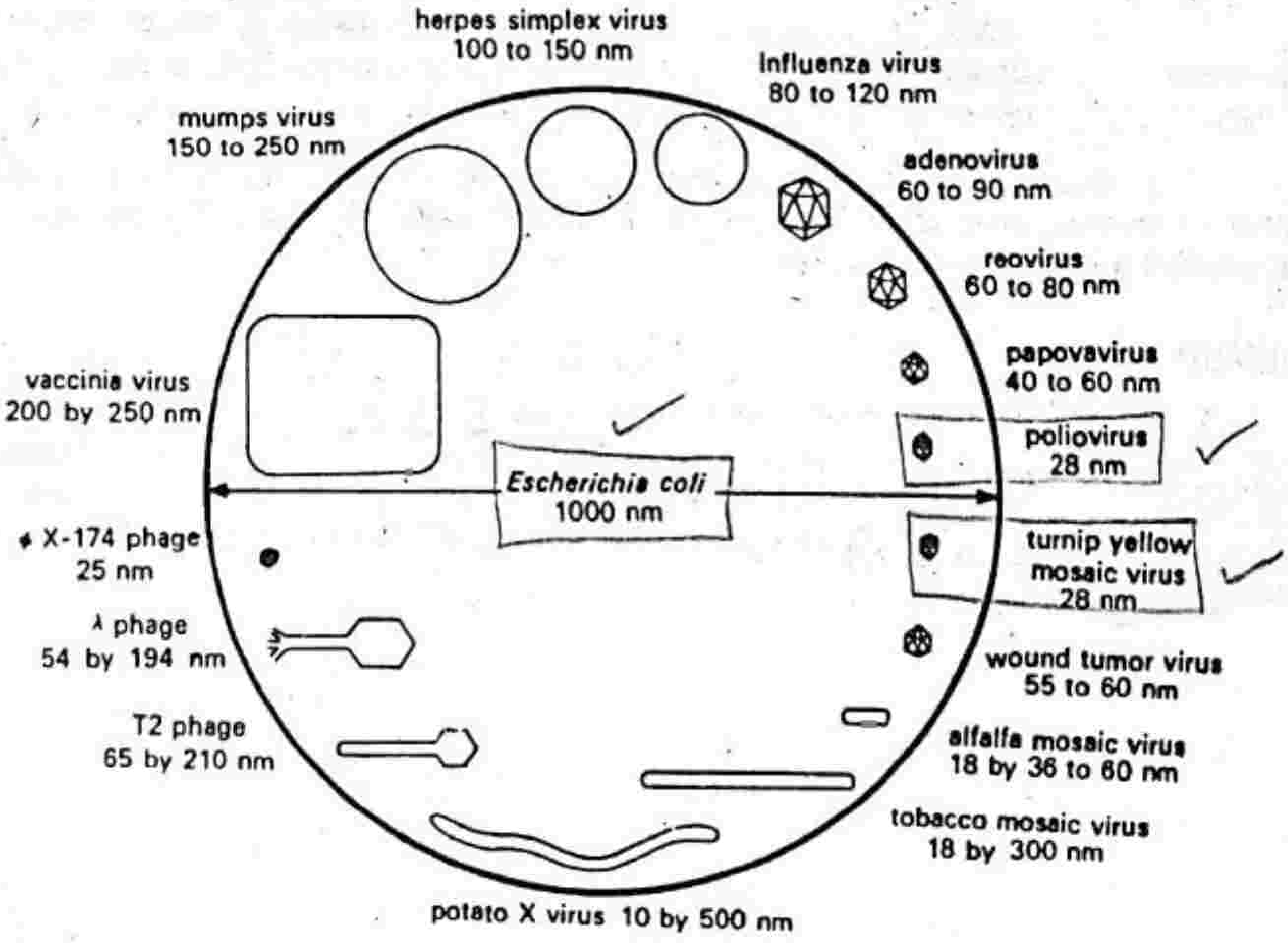


Fig. 1.1: Morphology and size range of virus particle.

Shape

The viruses exhibit a variety of shapes. They may be rod-like, i. e., elongated like a piece of insulated electrical cable (TMV); rounded (mump virus, herpes virus, influenza virus); tadpole-shaped (bacteriophage); or bullet-shaped (rabies virus).

Bacteriophages exist in different shapes, but most of them possess a polyhedral head and a tail through which they infect the host cell. Some bacteriophages are filamentous.

Generalized Structure of a Virus

The viruses are non-cellular and possess a very simple structure. Each virus consists of a DNA or RNA filament forming a core. The fully assembled, infective particle is called a virion.

Capsid

The virus DNA is surrounded by a coat of protein called a capsid. This structure formed of nucleic acid and capsid is generally termed nucleocapsid..

The capsid is made up of proteins. These include basic proteins, the histones; histone-like proteins (adenoviruses); or small peptides and polyamines (bacteriophages). Lipids and carbohydrates are also found in viruses. These include phospholipids, glycolipids, neutral fats, fatty acids, and cholesterol. Phospholipid is predominant in viral envelope.

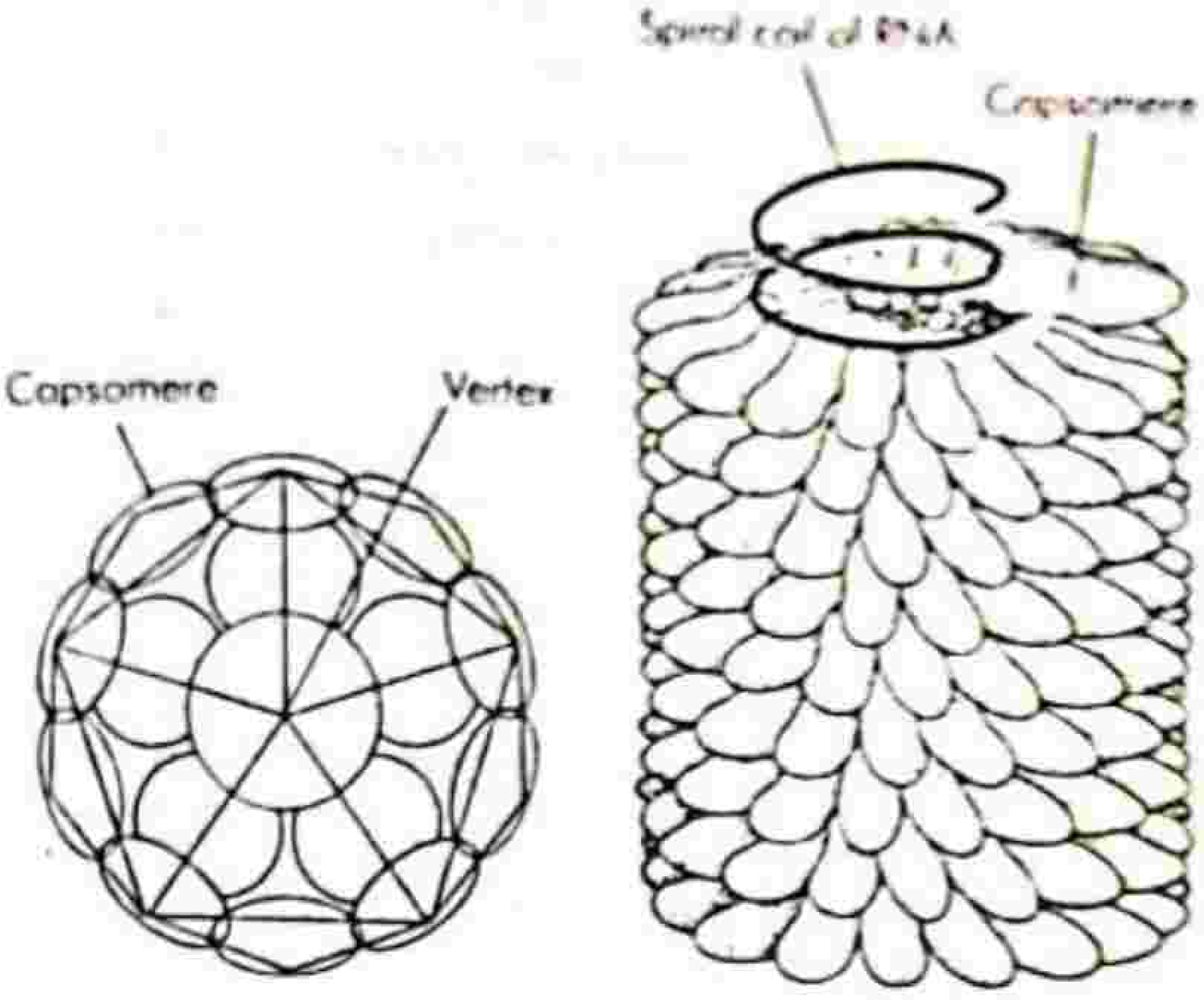
Capsomere

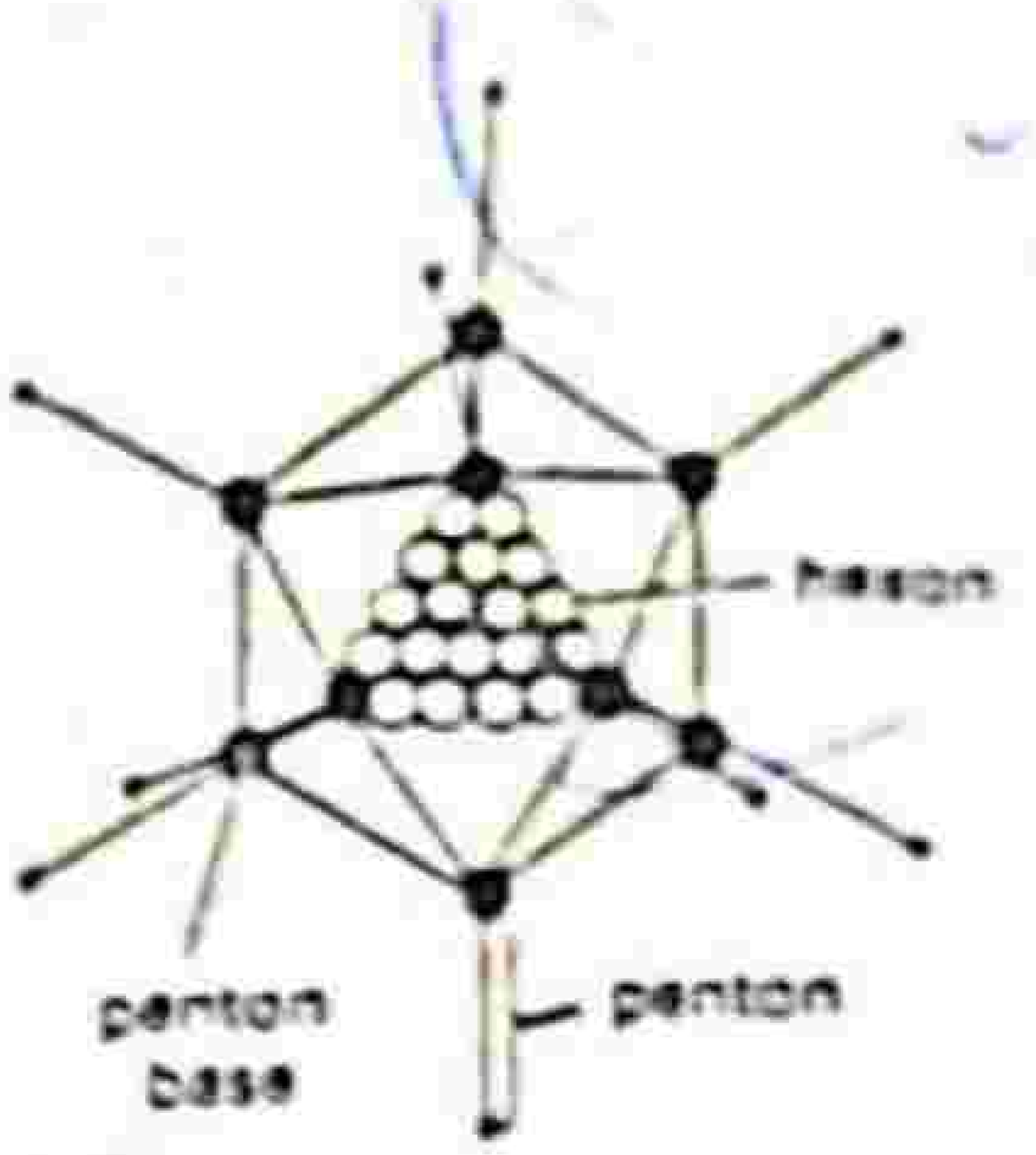
The virus coats (capsids) are often built up of identical repeating units called capsomeres. The capsomeres form highly symmetrical structures that can be crystallized and help to study their structure through X-ray crystallography and electron microscopy.

Most animal viruses such as herpes and influenza viruses, have an additional lipoprotein envelope derived from the surface membrane of the host cell. However, all the plant viruses and phages are naked.

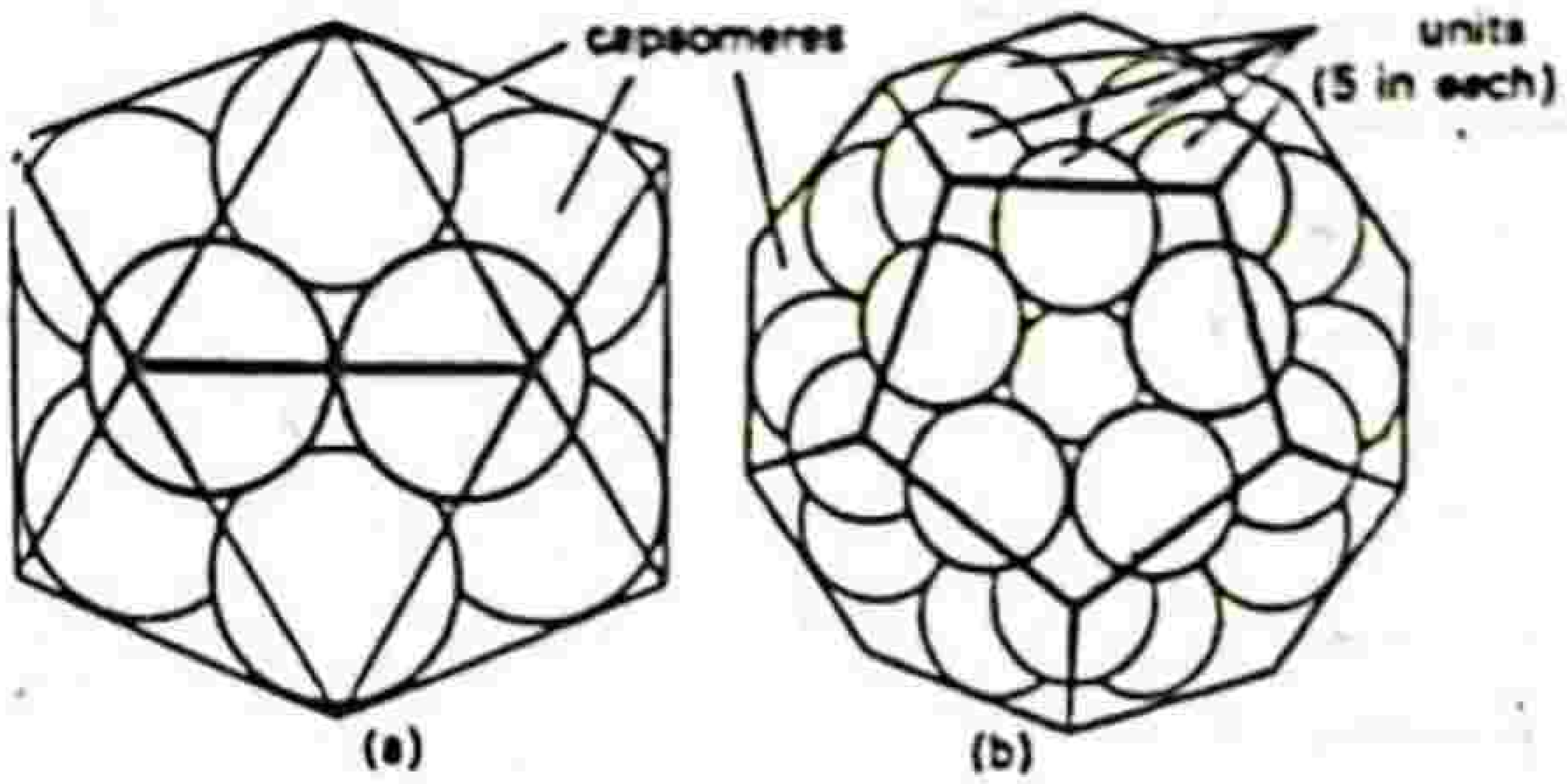
Viral Genome

The viral genome consists of nucleic acids. Bacteriophages and animal viruses contain DNA whereas plant viruses contain RNA usually. Both DNA and RNA never exist in the same virion. Virions that contain only a single copy of the nucleic acid are called haploid. However, retroviruses are contains two identical RNA single strands. So they are termed diploid.





Morphology of *Adenovirus*, a polyhedral virus



A cubic virus

Symptoms

Fig. 1.2: Symmetry of Viruses.

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BACTERIOPHAGE

Systematic Position

Division:	Vira
Subdivision:	Deoxyvira
Class:	Deoxybinala
Order:	Virales
Sub-order:	Phagineae
Name:	*Bacteriophage*

Expriments → Lysis agents)

(Named Bacteriophage

Bacteriophages are viruses that infect bacteria. They were discovered independently by Frederick W. Twort in England in 1915 and by Felix d'Herelle at the Pasteur's Institute in Paris in 1917. The term bacteriophage was coined by D'Herelle which means bacteria eater. Bacterial viruses are widely distributed in nature. Phages exist in almost all bacteria.

Structure and Composition

Like all viruses, the bacteriophages are composed of a nucleic acid core surrounded by a protein coat, the capsid made up of sub-units, the capsomeres.

Ultrastructure of T-even Phage

A T-even coliophage is tadpole shaped. It consists of a head and a tail.

([illegible]) edge shaped

Head

The head is in the form of a bipyramidal, hexagonal prism. The head consists of proteinaceous membrane enclosing a core of double-stranded viral DNA.

Tail

The tail is cylindrical attached to one end of the head. The tail is made up of four components.

It is a central helical hollow tube or core through which viral DNA passes during infection. The core is surrounded by a helical proteinaceous sheath. The sheath is connected to a thin disc or collar at the head end. The distal end of the sheath is connected to a hexagonal basal plate, which is of complex structure. The plate has a pin at every corner. The plate alongwith its pins is connected to six long thin tail fibers which are the organs of attachment to the wall of host cell.

(DNA → DNA → mRNA → Protien)

Biosynthetic machinary works as

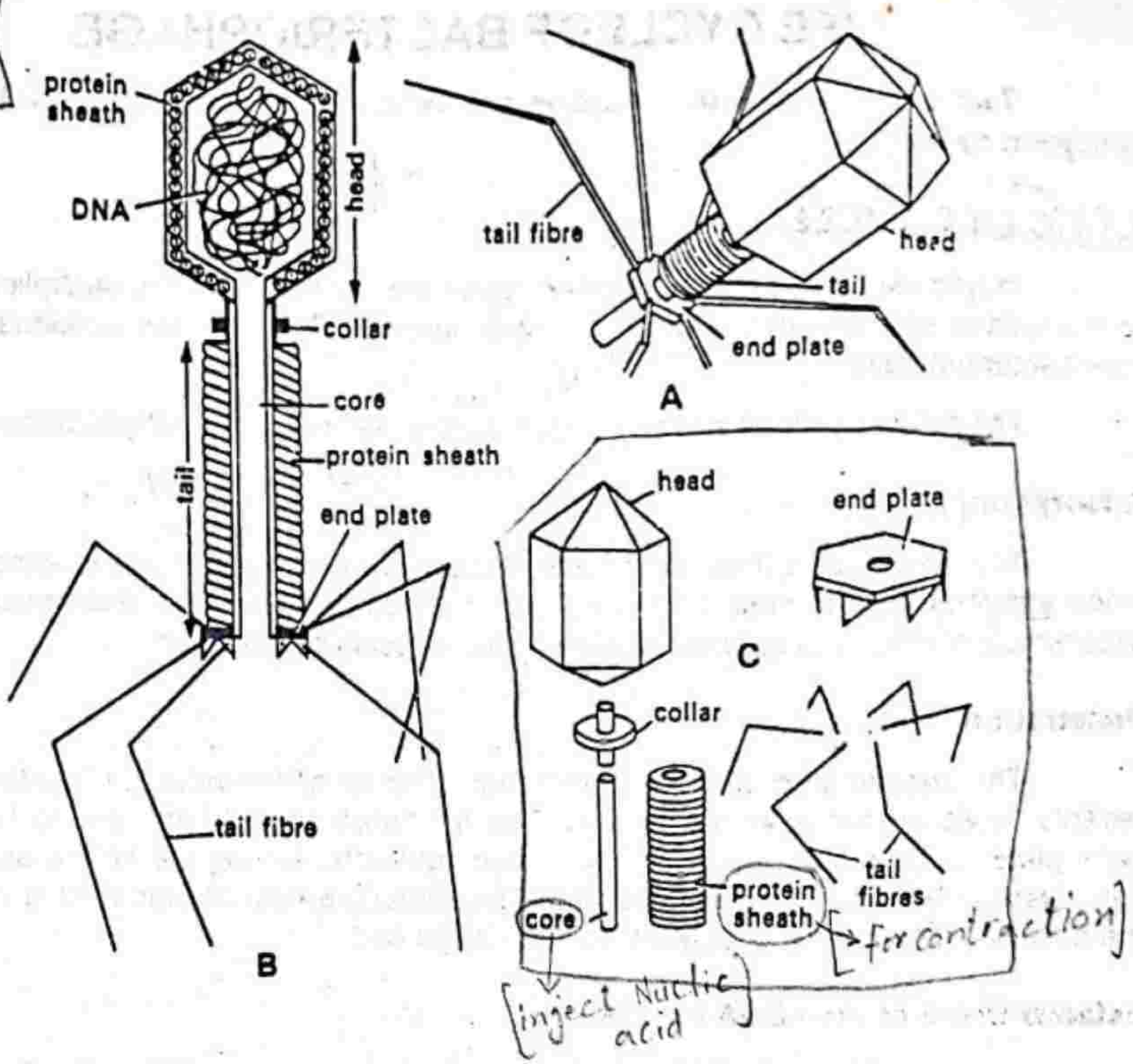
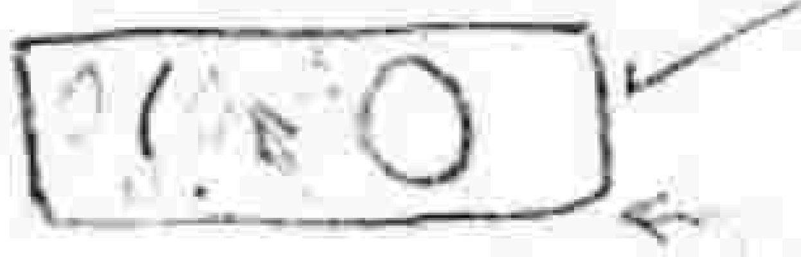


Fig. 1.3: Morphology of T-even bacteriophage virus.

Types of Bacteriophages

There are two main types of bacterial viruses:

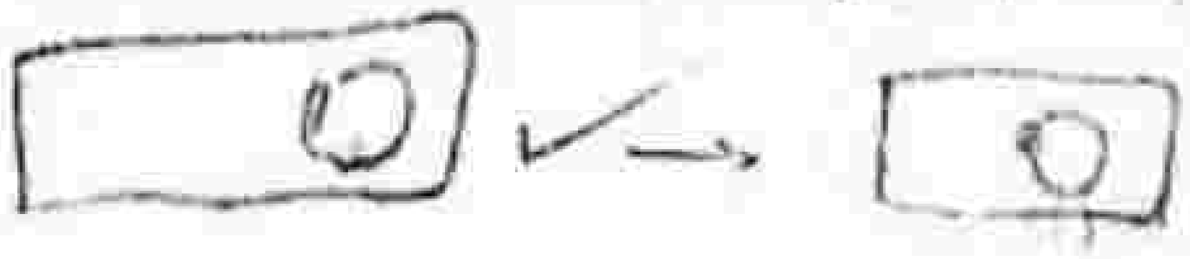
i.Lytic or Virulent Phages



These are phages that destroy (their host) bacterial cell after infection. They reproduce inside the cell and produce a large number of viruses. The host cell bursts to release new phages which infect other bacterial cells. They exhibit lytic cycle.

(Lysogenic)

ii.Temperate or Avirulent Phages



[illegible]

These are phages that do not harm and destroy the host bacterial cell. The viral nucleic acid is carried and replicated in the host bacterial cells without any damage for many generations. However, temperate phages may spontaneously become virulent at some subsequent generation and lyse the host cells, i. e, exhibit lysogenic cycle.

LIFE CYCLEOF BACTERIOPHAGE

Two different types of life cycles are exhibited by bacteriophages: lytic cycle or lysogenic cycle.

→ control on DNA of Bacteria and its degradation into piecis

LYTIC LIFE CYCLE

(Virus)(Virulent phage)

In lytic life cycle phage multiplies inside the host cell and the multiplication results in the lysis or disintegration of the host bacterium cell. The progeny is released to attack new bacterium cells.

The following steps can be noticed during the life cycle of a lytic bacteriophage:

Adsorption (Attachment)

The first step in infection of a host bacterial cell by a phage is adsorption. The virion attaches itself to host cell through ionic bonds or at more or less specific receptor sites which interact with specific proteins in the capsids or the virion.

Penetration

The second step is called penetration. The tip of the virus tail is attached to the receptor sites on bacterial cell surface. The tail fibers bend to anchor the tail pins and base plate to the cell surface. The tail sheath contracts, forcing the hollow spike into the cell. Lysozyme in the base plate helps the process. The viral nucleic acid is injected into the host cell. The protein coat remains outside the cell.

Establishment of Viral DNA in Host

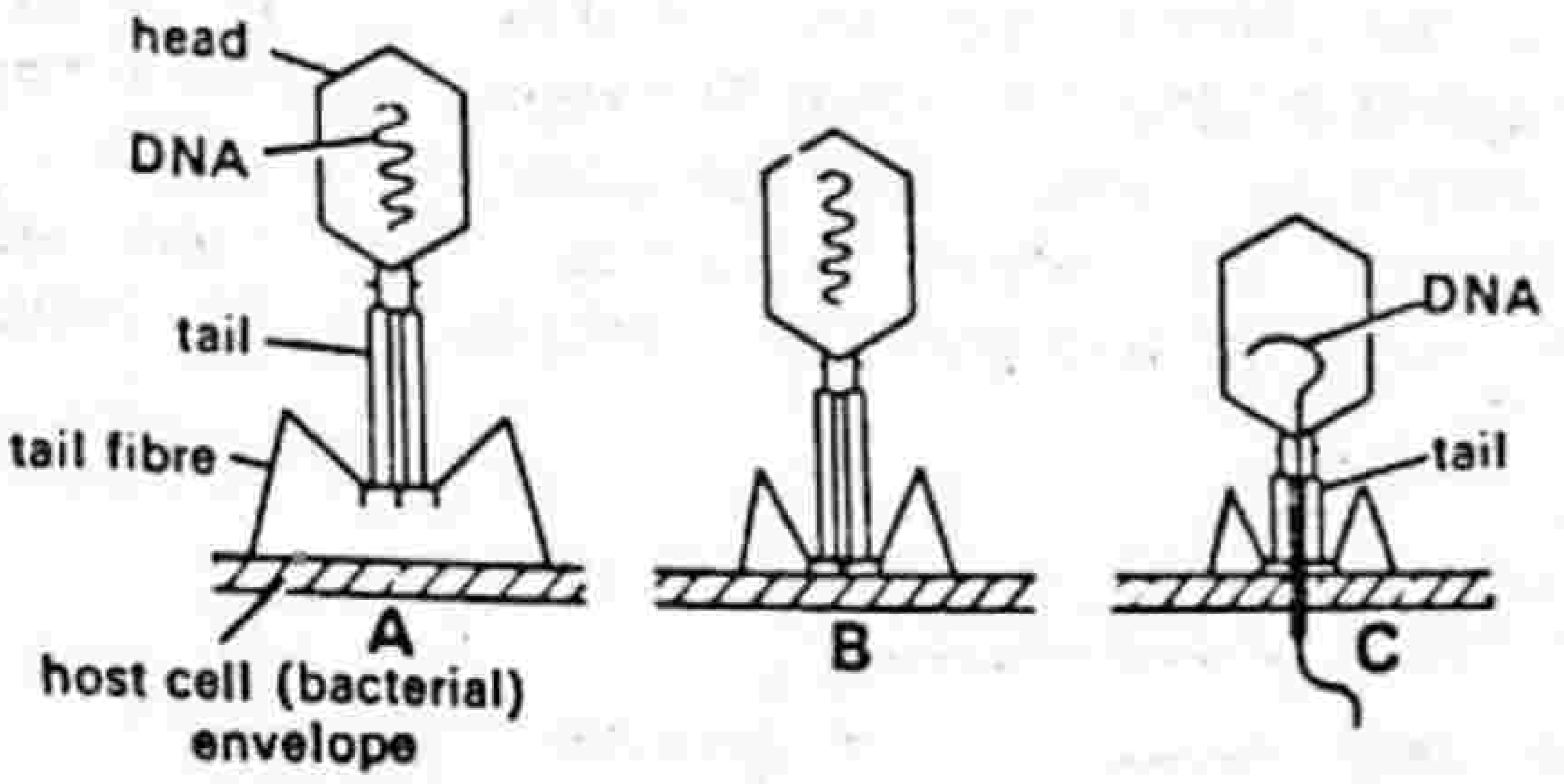
The viral DNA takes control of the cell metabolism and directs the bacterium for production of viral enzymes using ribosomes of host. These include nucleases that break down host DNA. Viral mRNA is formed which directs synthesis of viral proteins that assemble heads, tails and fibers.The viral DNA replicates and its amount increases. This phase of life cycle is called transcription.

Assemblyof Bacteriophage

While the synthesis of both structural proteins and nucleic acid is taking place, new phages begin to assemble. About 25 minutes after initial infection, some 200 new bacteriophages have been assembled.

Release of Bacteriophage

After assembly of phages, the bacterial cell bursts, releasing new phages to infect other bacteria and begin the cycle over again. The last phase is called assembly and release. The time taken from infection until lysis is called latent period.



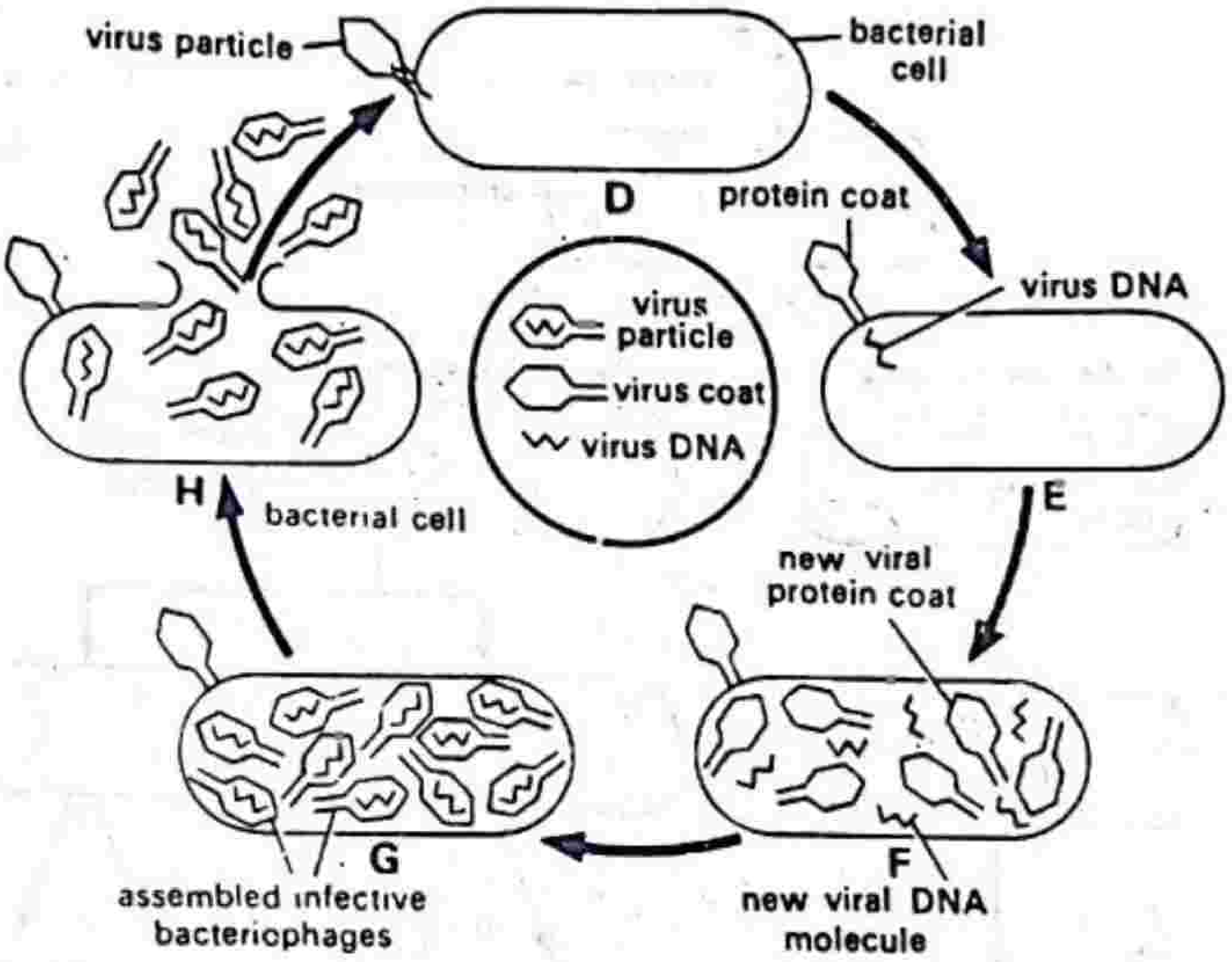


Fig. 1.4: Lytic life cycle of Bacteriophage

(Non-virulant) (incorporate with Bacterial DNA)

LYSOGENY OR LYSOGENIC LIFE CYCLE OF A BACTERIOPHAGE

Not all infections of bacterial cells by phages terminate in lysis. In some cases an entirely different relationship, known as lysogeny, meaning having potential for lysis, may develop between the virus and its bacterial host.

In lysogeny the viral DNA of the temperate phage, instead of taking over the function of the cell's genes, is incorporated into the host DNA and becomes a prophage in the bacterial chromosome, acting as a gene. In lysogeny, the bacterium metabolizes and reproduces normally, the viral DNA is transmitted to each daughter cell through all successive generations. Sometimes, however, for reasons unknown, the viral DNA is removed from the host chromosome and the lytic cycle occurs. This process is called spontaneous induction. A change from lysogeny to lysis can sometimes be induced by irradiation with ultraviolet light or by exposure to some chemicals.

Lysogeny has been studied best in coliphage lambda. It has been observed that the multiplication of phage is repressed inside the infected cell, because the genes responsible for phage multiplication and lysis are switched off. The phage possesses a gene that codes for repressor protein which makes the cell resistant to lysis initiated either by the prophage or another lytic virus. The repressor protein has been isolated and purified. It is an acidic protein. When the phage lambda is exposed to ultraviolet light, this introduces the synthesis of a protein in the host cell. This protein has proteolytic activity and cleaves the repressor protein preventing it to bind to the lambda prophage. This possibly induces lysis.

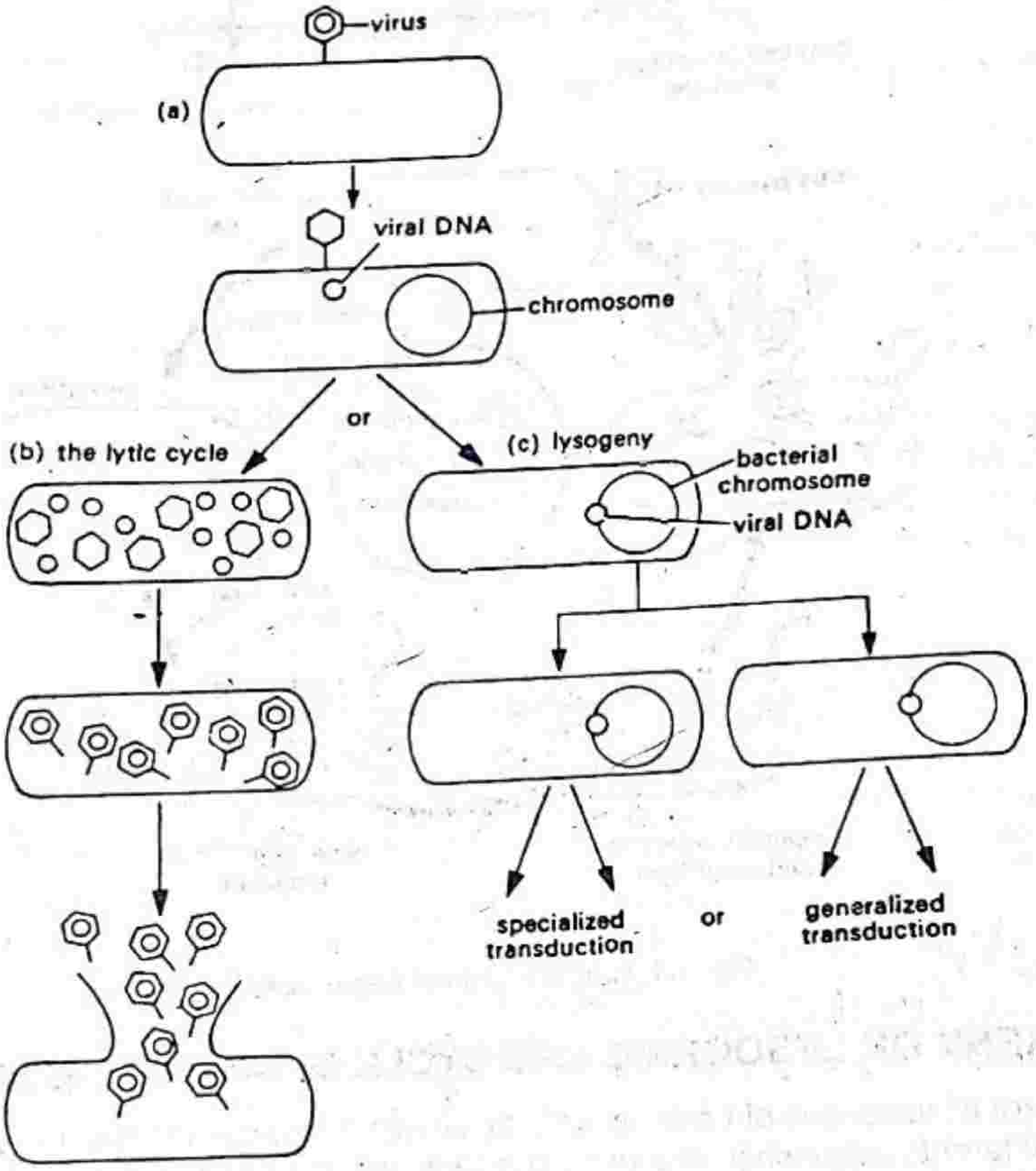


Fig. 1.5: Lytic & lysogenic life cycle of a T-phage.

TOBACCO MOSAIC VIRUS (TMV) DISEASE

The tobacco mosaic disease is caused by a rod-shaped virus. the tobacco mosaic virus (TMV). It is about 300 nm long and 15 nm in diameter and consists of a single strand of RNA protected with a capsid formed of protein sub-units. Its capsid is made from 2130 molecules of coat protein and one molecule of genomic single strand RNA 6400 bases long. The coat protein self-assembles into the rod like helical structure (16.3 proteins per helix turn) around the RNA which forms a hairpin loop structure. The protein monomer consists of 158 amino acids which are assembled into four main alpha-helices,Each subunit consists of 158 amino acids arranged in a helix. TMV is one of the most thermostablevirus known so far. It can withstand a temperature as high as 93oC.

Systematic Position

Division:	Vira
Subdivision:	Ribovira
Class:	Ribohelica
Order:	Virales
Family:	Marmotwceae
Genus:	*Marmora*

Symptoms

It is known to infect members of nine plant families especially solanaceae and at least 125 individual species, including tobacco, tomato, peppercucumbers, and a number of ornamental flowers.

The first symptom of this virus disease is a light green coloration between the veins of young leaves. This is followed quickly by the development of a "mosaic" or mottled pattern of light and dark green areas in the leaves. These appear as thick, elevated, blister-like areas. In these cases, large dead areas develop in the leaves. The plant growth is stunned and there is downward curling and distortion of leaves. The leaves may become narrow and elongated. These symptoms develop quickly and are more pronounced on younger leaves. Mosaic does not result in plant death, but if infection occurs early in the season, plants are stunted. Lower leaves are subjected to "mosaic burn" especially during periods of hot and dry weather. This constitutes one of the most destructive phases of tobacco mosaic virus infection. Infected leaves may be crinkled, puckered, or elongated. However, if TMV infects crops like grape and apple, it is almost symptomless.

Transmission & Infection

TMV survives in infected leaves and stalks in the soil or on the surfaces of contaminated seeds. The virus initially enters a plant through wounded tissues of seedlings or transplants in the fields. Then it spreads in the field. The infection is systemic invading the parenchyma cells and moving through phloem.

TMV is transmitted readily through mechanical sap, grafting and dodder. The most common method of transmission of TMV in field and greenhouse is through hands of workers handling infected and healthy plants.It enters the neighboring cells through plasmodesmata. It can also spread through phloem for longer distance movement within the plant. Moreover, TMV can be transmitted from one plant to another by direct contact.

Replication

Following entry into its host via mechanical inoculation, TMV un-coats itself to release its viral RNA strand. Then the viral genome will further replicate to produce multiple mRNAs. The resulting mRNAs encode several proteins, including the coat protein and an RNA-dependent RNA polymerase (RdRp), as well as the movement protein. Thus TMV can replicate its own genome. After the coat protein and RNA genome of TMV have been synthesized, they spontaneously assemble into complete TMV virions.

Control of Disease

The following steps help eliminating the disease:

1. The sanitation is the main method of disease control. The crop should not be grown at least for two years in the fields where diseased crop was grown.
2. Removal of diseased plants and weeds that harbour virus early in the season also helps in reduction and elimination of subsequent spread of virus.
3. Workers in the field must wash their hands with 3% trisodium phosphate or soap.
4. TMV resistant varieties of tobacco may be grown.
5. Coconut milk is found to be effective in the control of TMV.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What is plant diversity.
2. Differentiate between prokaryote and eukaryote.
3. Who discovered virus.
4. Give three characteristics of viruses.
5. What is capsomere.
6. What is viral genome.
7. Draw diagram of bacteriophage.
8. What is TMV.
9. What is lytic cycle.
10. How TMV can be controlled.

B. Long Questions

1. Describe life cycle of viruses.
2. Describe lytic and lysogenic cycle of bacteriophage.
3. What is TMV. Describe symptoms and control measures.
4. Write short note on structure of virus.

SECTION III

THE BACTERIA

13) Economic Important *(a) Useful bacteria (i) (Role in) Biotechnology (ii) Gen Engeri..
*(iii) Fiber Retting (iv) Digestion (v) Vitamin Synthesis (vi) Waste Disposal

Chapter 2

(b) Harmful Bacteria :- (i) Pathogens (a) Plant disease (b) Animal disease
(ii) Food Spoilage

Classification *(i) Archaebacteria (ii) Omnibacteria (iii) Cyanobacteria (iv) Chloroxybacteria
(v) Micoplasm + Spiroplasm (vi) Spirocheats (vi) Pseudomonas (vii) Actinomycetes

THEBACTERIA

(viii) Spirocheat (ix) Myxobacteria

(x) Nitrogen fixing Arobic bacteria (xi) Chemoautotrophic bacteria

Bacteria are the smallest organisms having a cellular structure. They are unicellular prokaryotic organisms classified as microorganisms. The study of bacteria is called bacteriology.

Occurrence

The bacteria occupy many environments, such as: soil, dust, water, air, in and on animals and plants and they can even be found in hot springs at temperatures of 70 °C or higher. Their numbers are enormous; one gram of fertile soil is estimated to contain 100 million and 1 cm^3 of fresh milk may contain more than 3000 million bacteria.

MCQ's

MORPHOLOGY OF BACTERIA

The morphology refers to size, shape, arrangement and structure of bacterial cells.

Size of Bacterial Cell

Bacteria are unicellular and very small. Most of them are approximately 0.5 to 1.0 um in diameter and from 0.1 to 10 um in length.

Shape of Bacterial Cell

The shape of a bacterial cell is governed by its rigid cell wall. Most bacteria have constant shape but some have cells that exhibit a variety of shape.

According to their shape the bacteria can be generally classified as:

a. Cocci: (O)

These are sphere-shaped bacteria, for example *Streptococcus pneumoniae* causing pneumonia.

b. Bacilli:

These are rodlike bacteria, for example Lactobacillus found in milk.

c. Spirilla:

They are rigid helical bacteria. These are usually curved with a twist or turn. A spirillum may have less than one complete twist and called vibrioid or one or more complete twists known as helical.

d. Spirochetes:

These are flexible and can twist and control their shape, whereas the spirilla are relatively rigid.

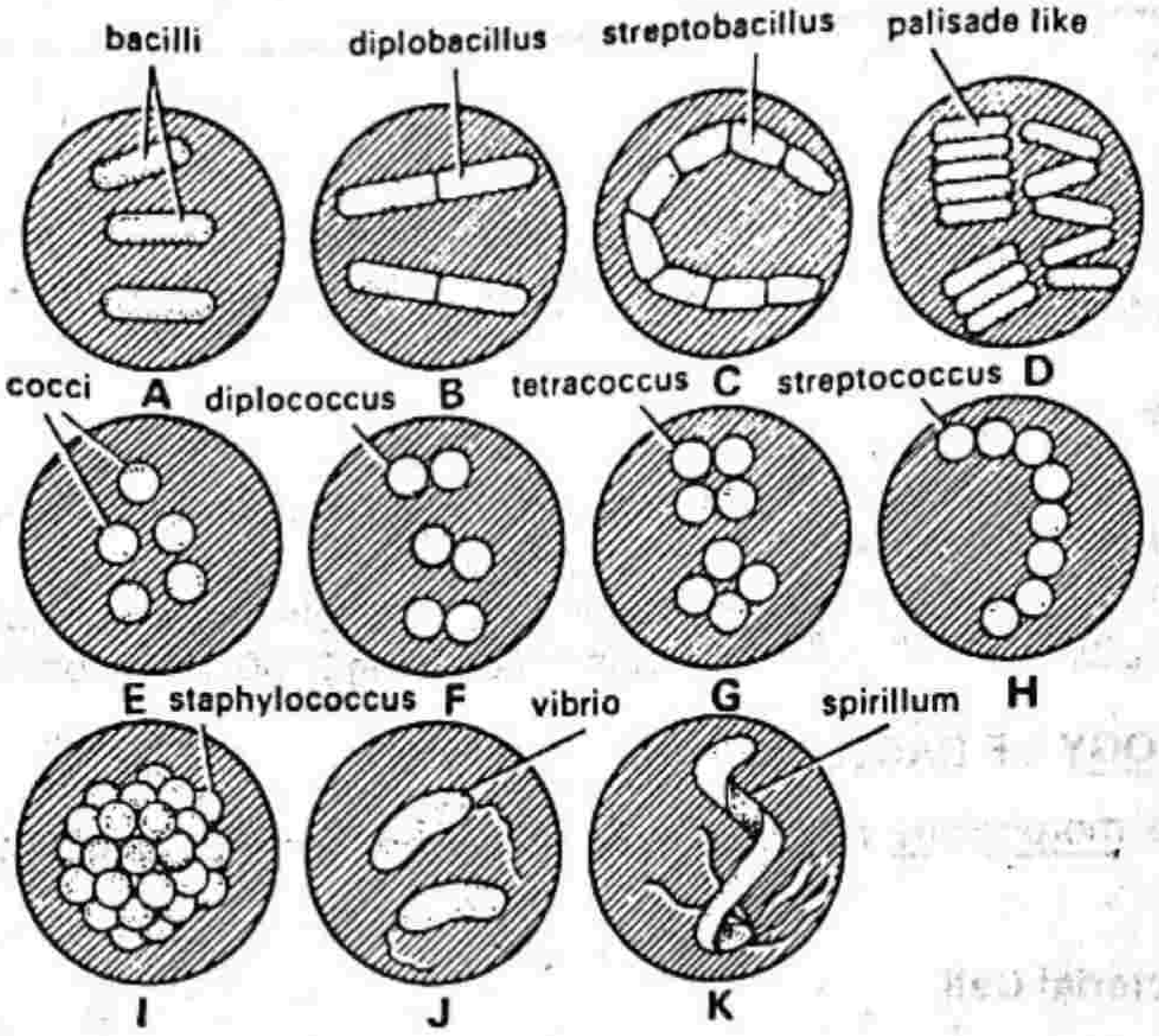


Fig. 2.1: Shape and arrangement of bacterial cells.

Arrangement of Bacterial Cells

The arrangement of bacterial cells is characteristics of their species. The most complex arrangement patterns are found in cocci.

The arrangement in cocci depends upon the plane of cell division and whether the daughter cells stay together after the division. They can be classified as:

a. **Diplococci:**The cells divide in one plane and remain attached in pairs.

b. **Streptococci:**The cells divide in one plane and remain attached to form chains.

c. **Tetracocci:**Cells divide in two planes and form groups of four cells.

d. **Staphylococci:**The cells divide in three planes, in an irregular pattern and produce groups of cocci.

e. **Sarcinae:**The cells divide in three planes, in a regular pattern, producing a cuboidal arrangements of cells.

The bacilli exhibit simple arrangement patterns and mostly occur singly. The most common arrangement patterns are:

a. **Diplobacilli:**The bacterial cells arranged in pairs.

b. **Streptobacilli:**The cells form chains.

c. **Hyphae:**Some species, for example *Streptomyces spp* form long, branched multinucleate filaments called hyphae which collectively form mycelium.

STRUCTURE OF BACTERIAL CELL

A bacterial cell consists of various components. Some of these are external and the others are internal to the cell wall. The external components include capsules and slime layers, flagella and pilli. Some structures are present only in certain species.

i.Capsule and Slime Layer

Many bacteria secrete sticky substance that form protective layers called capsule outside the cell wall. In some cases this layer is diffuse and known as slime layer. Most bacterial capsules are composed of polysaccharides while a few capsules are polypeptides. The glue-like nature of capsule helps bacteria to adhere to their substrate or unite to form colonies. The capsule provides increased resistance to disease-causing bacteria against antibiotics.

ii.Flagella

Most bacteria are motile and the organs of locomotion are hair-like, helical cytoplasmic appendages, the flagella. The flagella may be present at one or both ends of the bacterial cell. In some cases they appear along sides or all around the bacterium.

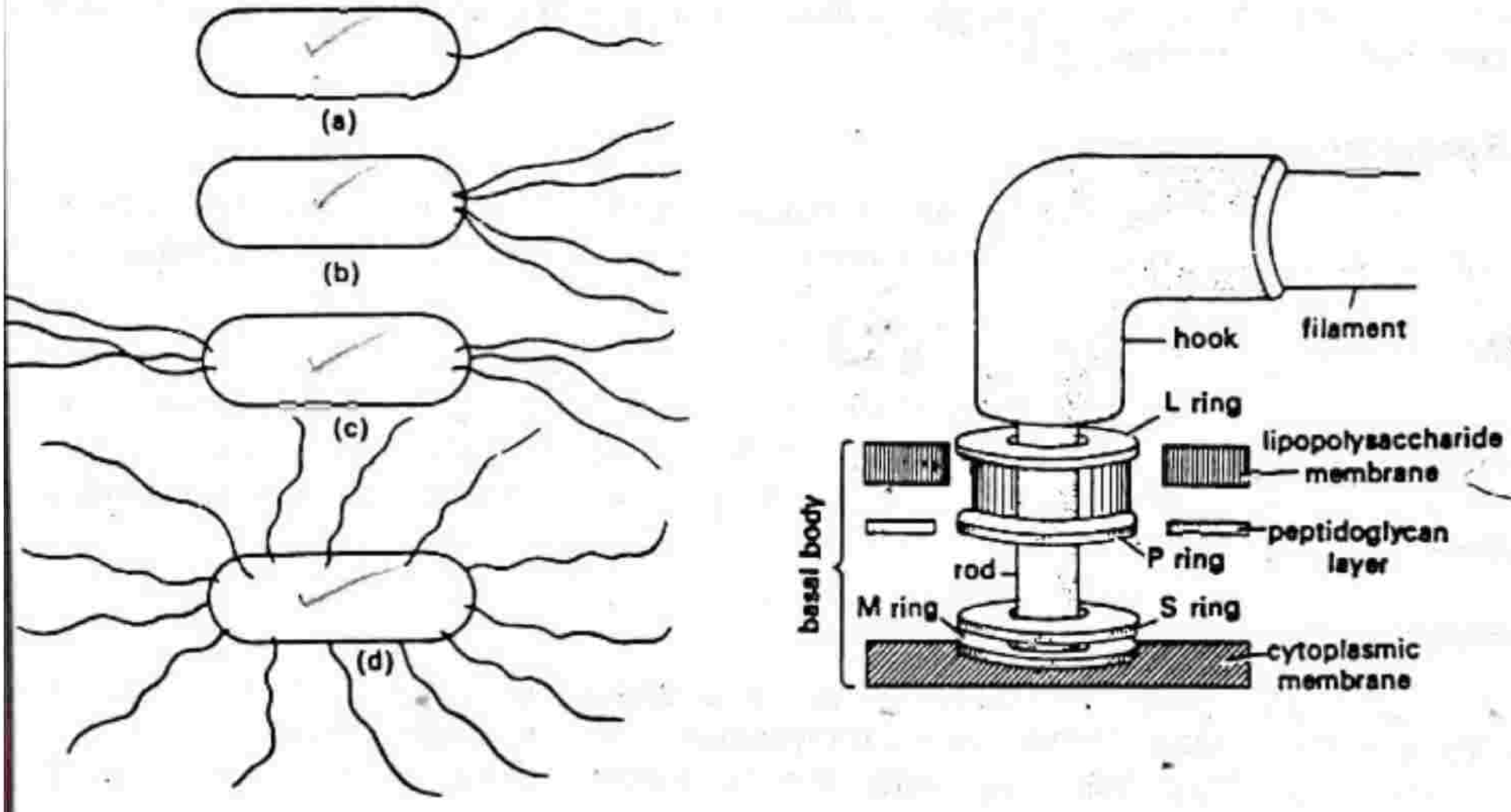


Fig. 2.2: Types of flagellation in bacterial cells and attachment of a flagellum.

iii.Pilli or Fimbriae

The motile as well as non-motile species possess hollow, filamentous rods called pilli or fimbriae. These are composed of a protein pillin. There are concerned with cell to cell attachment. The F pilus or sex pilus, are involved in bacterial mating during sexual reproduction.

iv.The Cell Wall

The cell wall is present beneath the capsule and external to cytoplasmic membrane. It is a rigid structure that gives shape to the cell. The cell wall is necessary for bacterial growth and development. The cells whose cell walls have been completely removed are incapable of normal growth and division.

Q:5

Gram-positive and Gram-negative Bacteria

On the basis of cell wall characteristics the bacteria can be divided into Gram-positive bacteria that can be stained with Gram's stain, and Gram-negative bacteria that do not retain the stain. The walls of Gram negative bacteria are thinner as compared to those of Gram positive bacteria. In both cases the wall consists of an insoluble, porous network formed of peptidoglycan, also called murein. It is a sac-like macromolecule consisting of parallel polysaccharide chains cross-linked in a regular fashion by short peptide chains. Gram-positive bacteria usually have a much greater amount of peptidoglycans in their cell walls than Gram-negative bacteria. In Gram-negative bacteria, the murein layer is coated on the outside with a smooth, soft lipid layer which protect them against antibacterial enzymes (lysozyme).

v. Cytoplasmic Membrane

It is present immediately beneath the cell wall and surrounds the living matter of the bacterial cell. It is semi-permeable membrane and composed of phospholipid (about 20 to 30 percent) and proteins (about 60 to 70 percent). The phospholipids form a bilayer in which most proteins are embedded. It also acts as site of energy production (ATP) and attachment for the bacterial DNA.

vi. Specialized Membranes

The cytoplasmic membrane produces infoldings that form complex internal structures and also increase its surface area. Two important specialized membranes are:

✓

a. Mesosomes

Mesosomes are infoldings of the cell surface membrane. They appear to be associated with DNA during cell division, facilitating the separation of the two daughter molecules of DNA after replication and aiding in the formation of new cross-walls between the daughter cells.

✓

b. Photosynthetic Membranes

✓ Among photosynthetic bacteria, tubular or sheet-like infoldings are produced by cytoplasmic membrane. These resemble thylakoids in Cyanobacteria (blue-green algae) and contain photosynthetic pigments, the bacteriochlorophyll. These are sites of photosynthesis.

vii. The Cytoplasm

The cell material bounded by the cytoplasmic membrane is cytoplasm. It can be differentiated into a liquid part called cytosol, an area in which nuclear material is concentrated, and a portion rich in ribosomes.

a. Cytosol:

The cytosol is a complex, concentrated solution of inorganic acids, amino acids, proteins, peptides, nitrogenous bases, vitamins, enzymes, coenzymes which provides chemical environment for metabolic and cellular activities.

b. Ribosomes:

The ribosomes are RNA-protein bodies that lie freely in the cytoplasm mostly, and concerned with protein synthesis. They are seen as dense particles, the polysomes. Each ribosome consists of two subunits, a 50S and a 30S subunit formed of equal amounts of RNA and protein. They are smaller in size than the ribosomes found in eukaryotic cells and sediment at 70 Svedberg units (70S).

c. Nucleoid— Bacterial Chromosome:

The bacterial chromosome consists of DNA molecule formed of about 5 x 106 base pairs and about 1 mm in length. Very little protein is associated with it. The bacterial chromosome is primitive and usually referred to as nucleoid.

In most bacteria, the DNA is concentrated as a mass of fibers and the region of the cytoplasm containing it stains less than surrounding cytoplasm. It is called nucleoid region or nuclear body. In *Escherichia coli*, the bacterial chromosome is in the form of a ring of double-stranded DNA molecule.

viii.Plasmids

In addition to the normal DNA chromosome, the bacterial cell may have much smaller rings of DNA called plasmids. Each plasmid consists of few genes and is capable of self-replicating independent of main chromosome. There are certain plasmids that provide resistance to cells against antibiotics or disinfectants. They contain genes whose products (enzymes) destroy these substances. Others help in cleaning oil spills and producing protein from petroleum. There are certain plasmids that are capable of integrating into the bacterial DNA chromosome, they are called episomes.

ix.Spores and Cysts

Bacteria produce resistant bodies called spores either within cells (endospores) or external to cell (exospores) for example in *Bacillus* and *Clostridium* spp. These can resist heat, desiccation and radiation and help to overcome unfavourable growth conditions. At the advent of favourable conditions, the spores germinate to form a new cell.

In some bacteria, for example *Azotobacter*, whole cell develops into a thick-walled, resistant body called cyst. These germinate into new individuals when the conditions are favourable for growth.

x.Gas Vacuole

Some aquatic species form gas vacuoles that provide buoyancy. These are hollow, rigid cylinders with a protein boundary impermeable to water, however dissolved gases can penetrate the boundary.

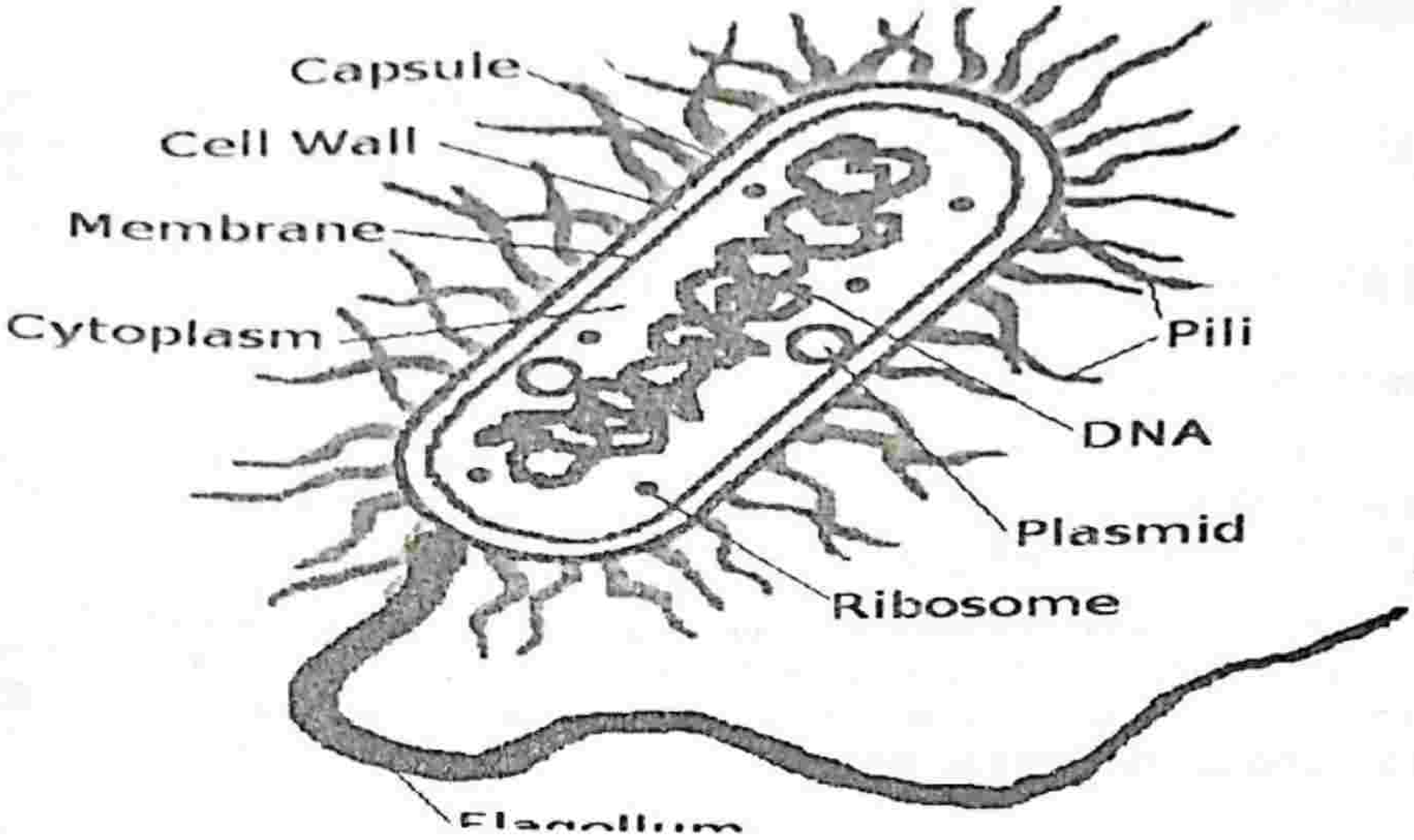


Fig. 2.3: Structure of a typical bacterial cell.

Q:2

GROWTH IN BACTERIA

In case of bacteria the term growth refers to changes in the total population rather than increase in the size or mass of an individual organism. The bacteria can grow rapidly because they have a large surface area to volume ratio and can therefore gain food rapidly from their environment by diffusion and active transport. Certain environmental factors such as temperature, nutrient availability, pH, and ionic concentrations affect growth. Under ideal conditions cell division may take place every 20 minutes. The number of cells double at each division. It is called exponential growth and the time interval is known as generation time. Followings are the different phases of bacterial growth

① Lag Phase

The exponential growth exhibit an initial period when there appears to be no growth, it is called lag phase. During this phase the bacteria adapt themselves to new environment.

② Log Phase

Lag phase is followed by a period of rapid growth known as log phase. In this growth the bacterial count increase rapidly.

③ Stationary Phase

After lag period growth seems to slow down as there is much greater competition for resources. The rate of production of new cells stops. The number of living cells remains constant. This is stationary phase.

④ Death Phase

Lastly, there is a decline in the viable (living) population. This is called decline phase. This phase is due to exhaustion of essential nutrients and accumulation of toxic waste products.

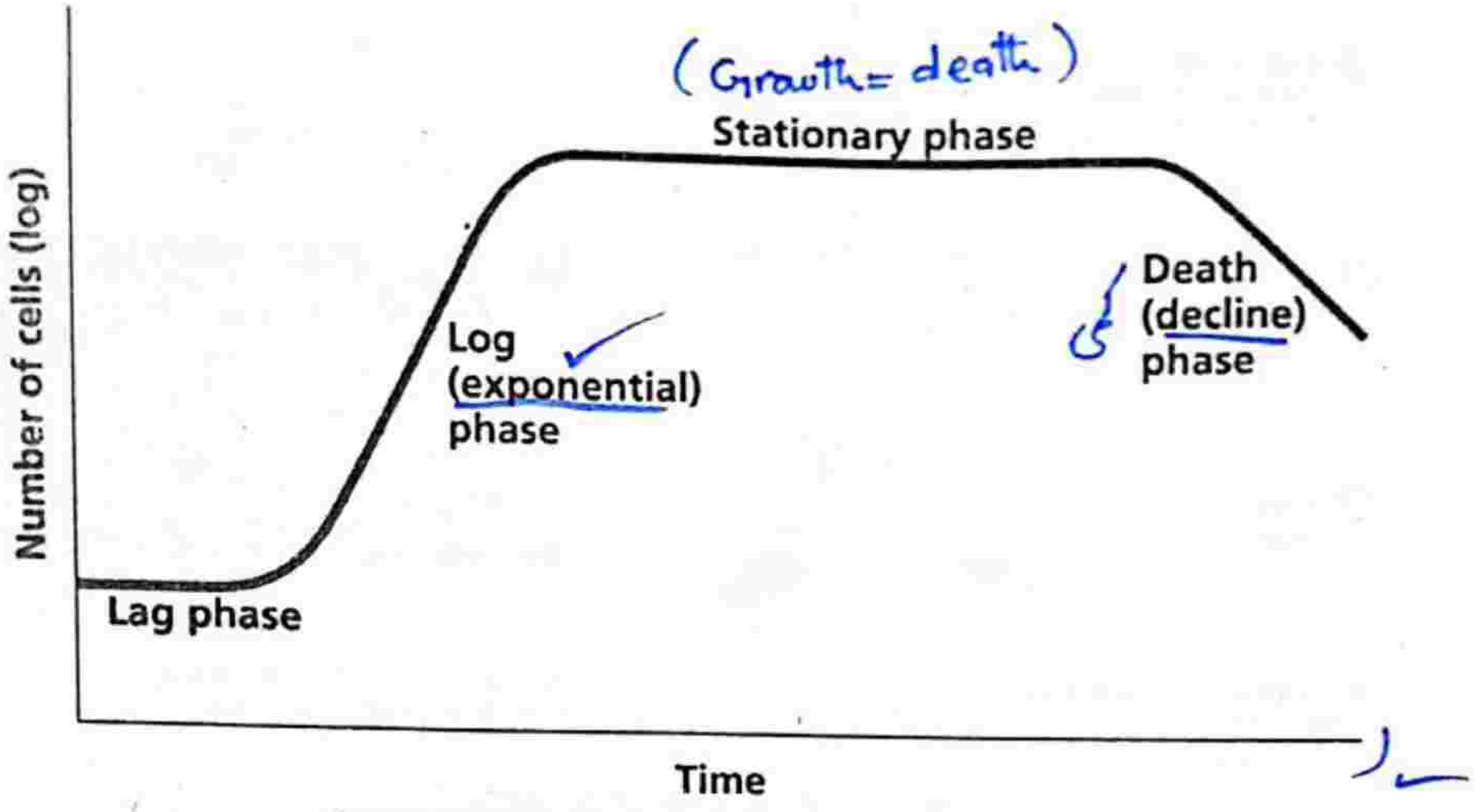


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Fig. 2.4: Growth Curve of Bacteria.

REPRODUCTION

The most common method of reproduction in bacteria is sexual reproduction, but they also reproduce sexually by genetic recombinations, a primitive type of sexual reproduction.

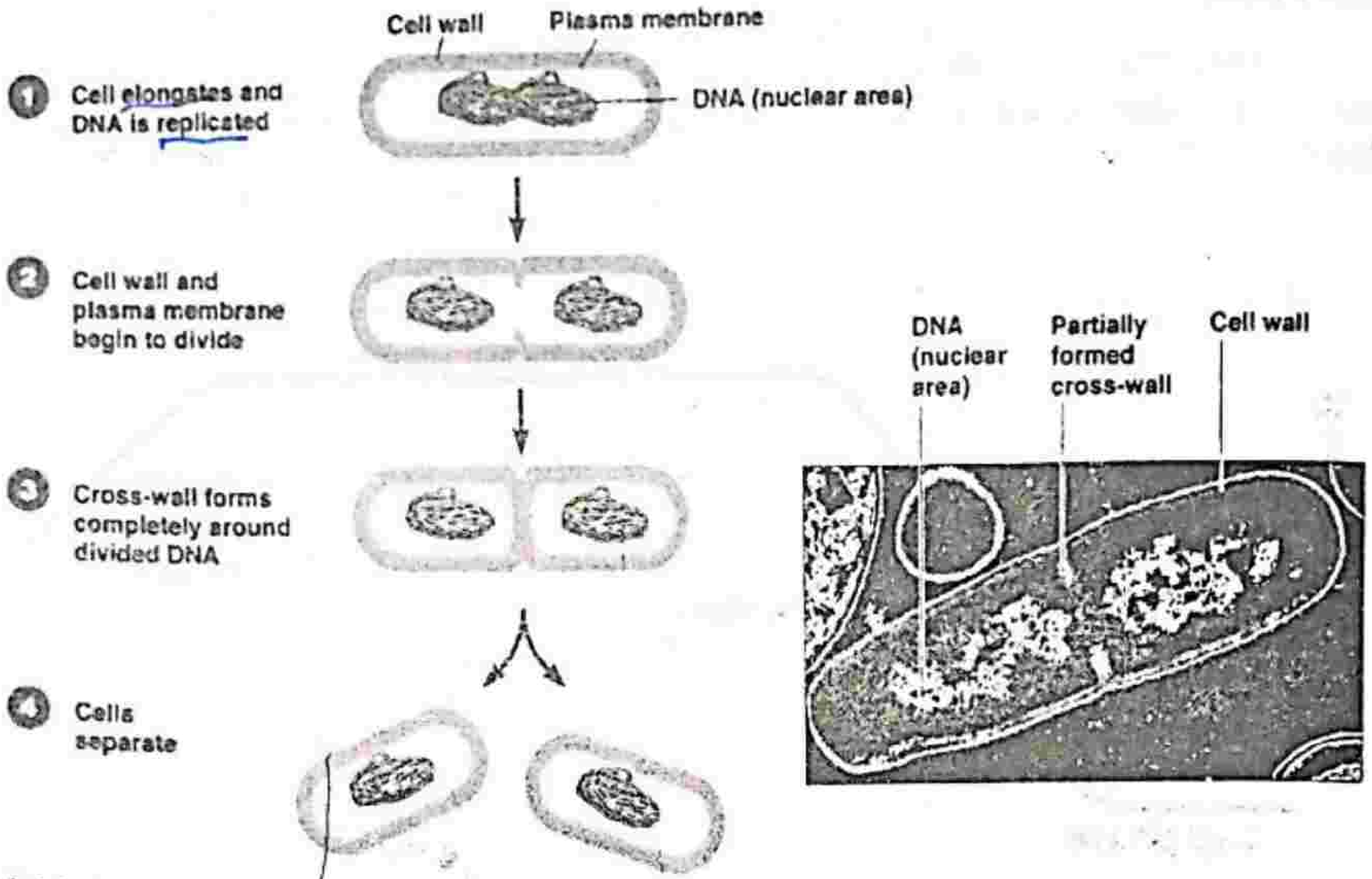
① Asexual Reproduction

The usual methods of asexual reproduction are binary fission and endospore formation.

ٹوٹنا دومیں Q.5

(a) Binary Fission

It is the most common way of asexual reproduction in bacteria. It takes place when the conditions become suitable for growth. A cell grows twice to its size and then divides into two identical daughter cells. Each daughter cell grows to the size of the parent cell. The process is sometimes referred to as life cycle.


Cell wall
Plasma membrane
DNA (nuclear area)
1 Cell elongates and DNA is replicated
2 Cell wall and plasma membrane begin to divide
3 Cross-wall forms completely around divided DNA
4 Cells separate
DNA (nuclear area)
Partially formed cross-wall
Cell wall

(a) A diagram of the sequence of cell division.

(b) A thin section of a cell of *Bacillus licheniformis* starting to divide.

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Fig. 2.5: Binary fission in a bacterium.

Mechanism of Binary Fission

Before fission, the bacterial cell takes up nutrients from its environment, synthesize cell substances such as RNA, DNA, proteins, enzymes and other macromolecules. The cell mass and cell size increase, and new cell wall material is synthesized. The DNA replicates and cytoplasmic membrane grows inward at the middle of the cell. The DNA is attached to mesosome which holds it in position during replication. The inward growth of cell wall results in formation of a septum that separates the two ⑦ daughter cells.

(b) Endospore Formation :

Endospores are spherical, oval (*Clostridium*), ellipsoidal (*Bacillus*) or cylindrical mass of protoplast surrounded by a multi-layered wall. They may develop in terminal, sub-terminal or central region of the cell. The outermost wall layer is delicate and called exosporium. Beneath it there is spore coat composed of several layers of proteins. The spore coat is followed by a thick cortex formed of a specific peptidoglycan. The protoplast contain a complex of calcium and dipicolinic acid (DPA) which provides heat resistance.

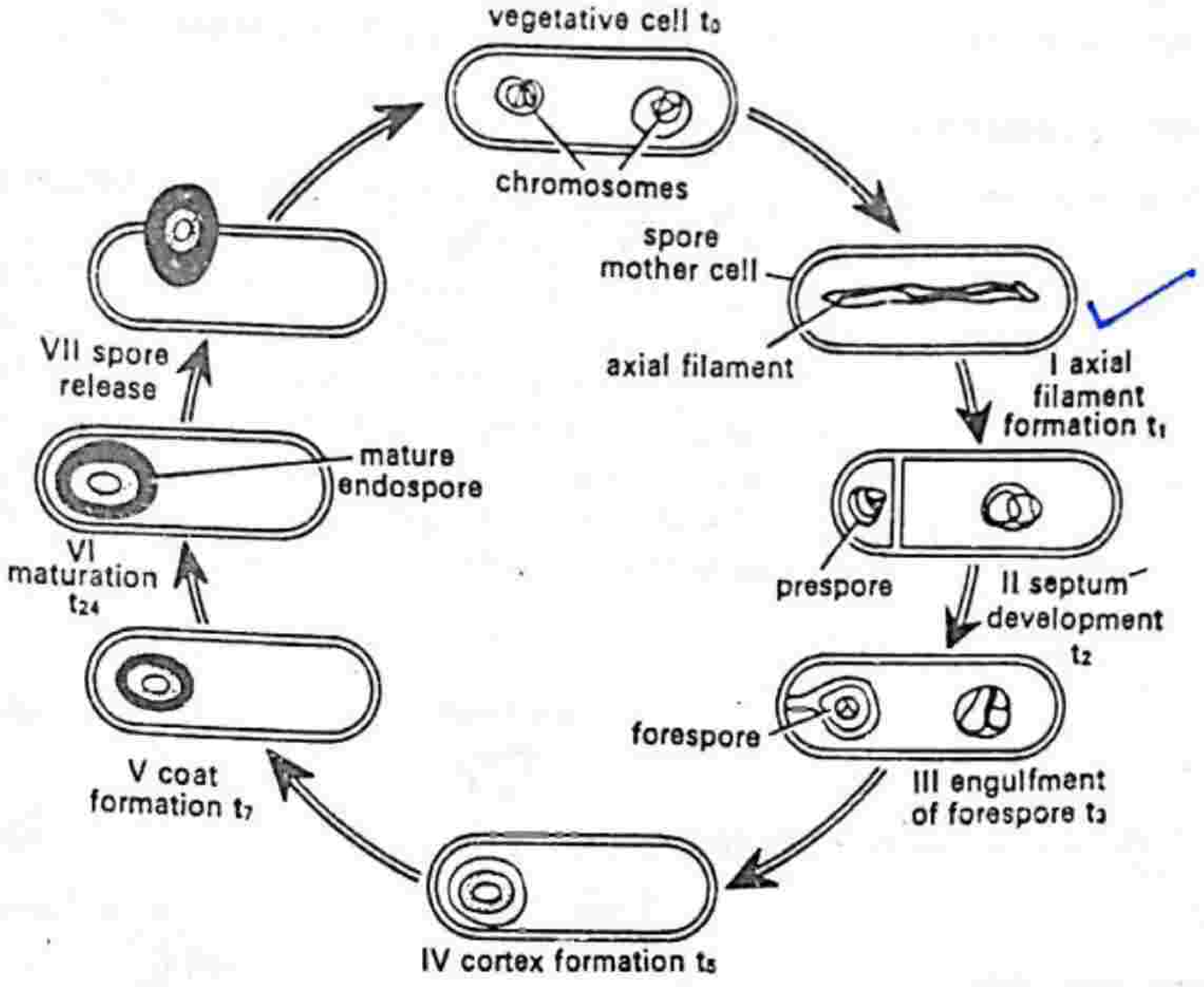


Fig. 2.6: Endospore formation in a bacterium.

② Sexual Reproduction

The sexual reproduction in bacteria is by genetic recombination. It is the formation of new genotype by recombination of genes following an exchange of genetic material between homologous chromosomes. It is regarded as a primitive form of sexual reproduction. It differs from eukaryotic sexual reproduction in absence of gamete formation and fertilization.

Bacterial Recombination

In bacterial recombination the cells do not fuse, and usually only a portion of the DNA from the donor cell is transferred to the recipient cell. Inside the recipient cell the donor DNA fragment is positioned alongside the recipient DNA in such a way that homologous genes are adjacent. Enzymes act on the recipient DNA, causing nicks and removal of a fragment. The donor DNA is integrated into the recipient DNA in place of the removed DNA. The recipient cell then becomes the recombinant cell because its DNA contains DNA of both the donor and the recipient cell. Such DNA is known as recombinant DNA.

Methods of Bacterial Recombination

In bacteria, genetic recombinations result from three types of gene transfer:

i. **Transformation:** Transfer of cell-free DNA from one cell to another. without any external factor force.

ii. **Conjugation:** Transfer of genes between cells that are in physical contact with one another.

iii. **Transduction:** Transfer of genes from one cell to another by a bacteriophage.

Q:3

TRANSFORMATION

The first evidence of genetic recombination or exchange of hereditary material in bacteria was noted by Griffith in 1928 during his transforming experiment.

Transforming Experiment

Griffith while working with *Streptococcus pneumoniae*, a bacterium that causes pneumonia fever, found that there were two strains of bacterium. One was capsulated, cause disease and form smooth colonies when grown on nutrient agar. It was called S-type. The other was non-capsulated, do not cause disease and form rough colonies when grown on nutrient agar. It was named R-type. Griffith injected a mouse with living R-cells and heat-killed S-cells. The mouse died within few days after infection. Griffith isolated living S-cells from blood of the dead mouse. Griffith concluded that heat-killed S-cells released a factor which enabled the R-cells to develop capsules and become virulent. The transformation was found to be heritable. Griffith termed it as transforming principle.

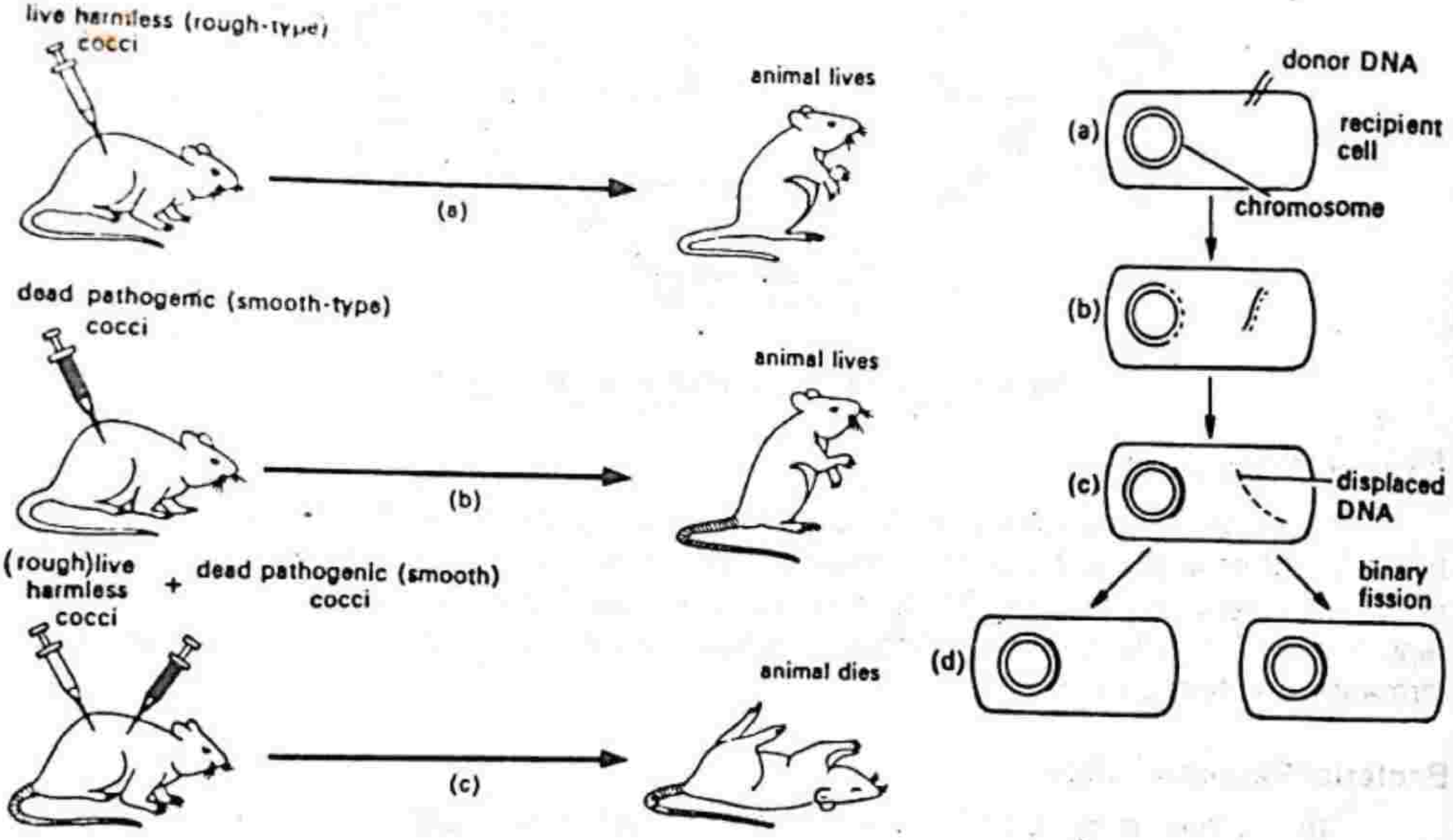

live harmless (rough-type) cocci
animal lives
(a)
dead pathogenic (smooth-type) cocci
animal lives
(b)
(rough) live harmless cocci
+
dead pathogenic (smooth) cocci
animal dies
(c)
donor DNA
(a)
recipient cell
chromosome
(b)
(c)
displaced DNA
binary fission
(d)

Fig. 2.7: Griffith's transformation experiment and mechanism of transformation.

Identification of Transforming Principle ✓

Avery, Macleod and McCarty in 1944 isolated and identified the transforming principle to be DNA. They defined it as genetic material of bacteria and transforming agent. It is now known that during transformation a short piece of DNA is released by the donor and actively taken up by the recipient, where it replaces a similar piece of DNA. Since 1940, transformation has also been demonstrated in *Bacillus*, and *Azotobacter* species.)✓

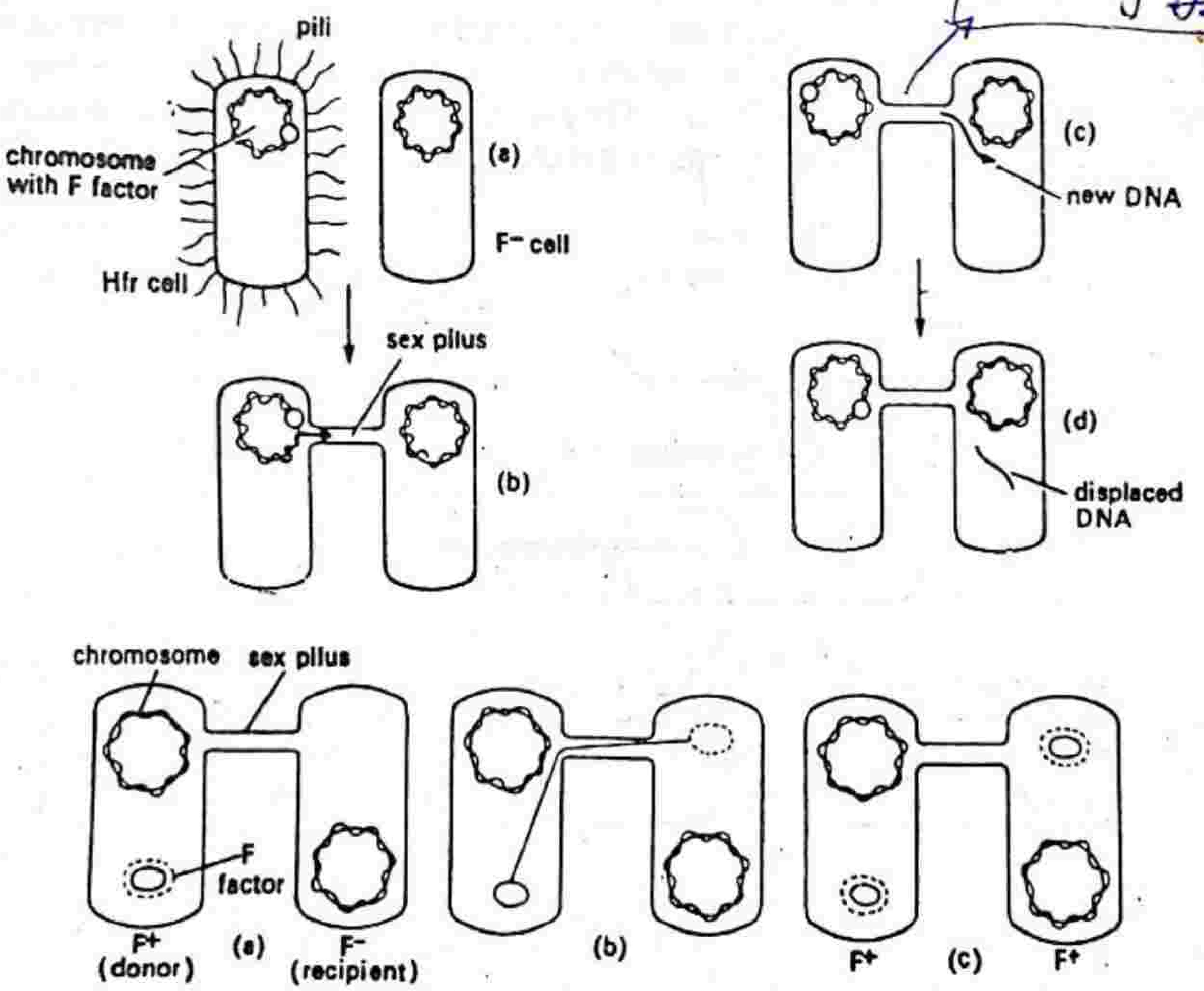
BACTERIAL CONJUGATION

Conjugation involves transfer of DNA between cells in direct contact through conjugation tube.

The process was first demonstrated experimentally by Joshua Lederberg and Edward Tatum in 1946, in Escherichia coli. They observed that normally E. coli can synthesize all the amino acids required by it, if given a supply of glucose and mineral salts. Lederberg and Tatum induced mutations by exposing the bacteria to radiations. They obtained two mutants, one mutant was unable to synthesize biotin (a vitamin) and amino acid methionine and the other could not synthesize amino acids threonine and leucine. Both the mutants were mixed and cultured on a medium lacking all the four factors. Theoretically none of the cells should have grown, but a few hundred colonies developed, each from one original bacterium. This suggests exchange of genetic information. The transformation was ruled out as no chemical was isolated. Later electron microscope revealed that direct cell contact or conjugation takes place in E. coli.

چاروں radiation ڈالی۔

✓ conjugation



✓

Fig. 2.8: A. Conjugation between Hfr and F cells; B. Passage of F-factor from donor cell to a recipient cell during conjugation.

(a)

Sex Factors

A clearer understanding of conjugation in bacteria came about through the experiments by Francois Jacob and Elie L. Wollman suggesting that different mating types exist in E. coli. Some bacteria contain an extrachromosomal piece of DNA called sex factor or F-factor (fertility factor). These cells were named male or F+ and these are donor cells. The cells without F factor were called female or F- and they are recipient cells. E. coli are coated with hair-like pilli, but the F+ contains one to three additional pilli, the F pilli or sex pilli which are responsible for physical contact between the cells. Later new strains of F+ cells were discovered which undergo sexual reproduction with F- cells are greater rate. These strains are called high frequency recombination strains or Hfr strains. This discovery helped in better understanding of conjugation.

During conjugation the F+ and F- cells establish physical contact and a tube called conjugation tube is formed between them. The F factor unwinds and replicates. A single-stranded F factor crosses to the recipient cell through the sex pilus. DNA replication occurs in both donor and recipient cell so that double-stranded nature of the DNA is re-established in both cells.

Q:4 TRANSDUCTION *

Transduction is the transmission of a double-stranded piece of DNA from a donor cell to a recipient cell through a third party usually a bacteriophage.

The phenomenon was discovered by Zinder and Lederberg in 1952 when they were searching for sexual conjugation in Salmonella typhimurium, a bacterium that causes typhoid in mouse. They mixed mutants unable to synthesize certain nutrients and cultured on medium lacking these factors. They isolated recombinants able to synthesize all the nutrients. This suggests exchange of genetic material through conjugation.

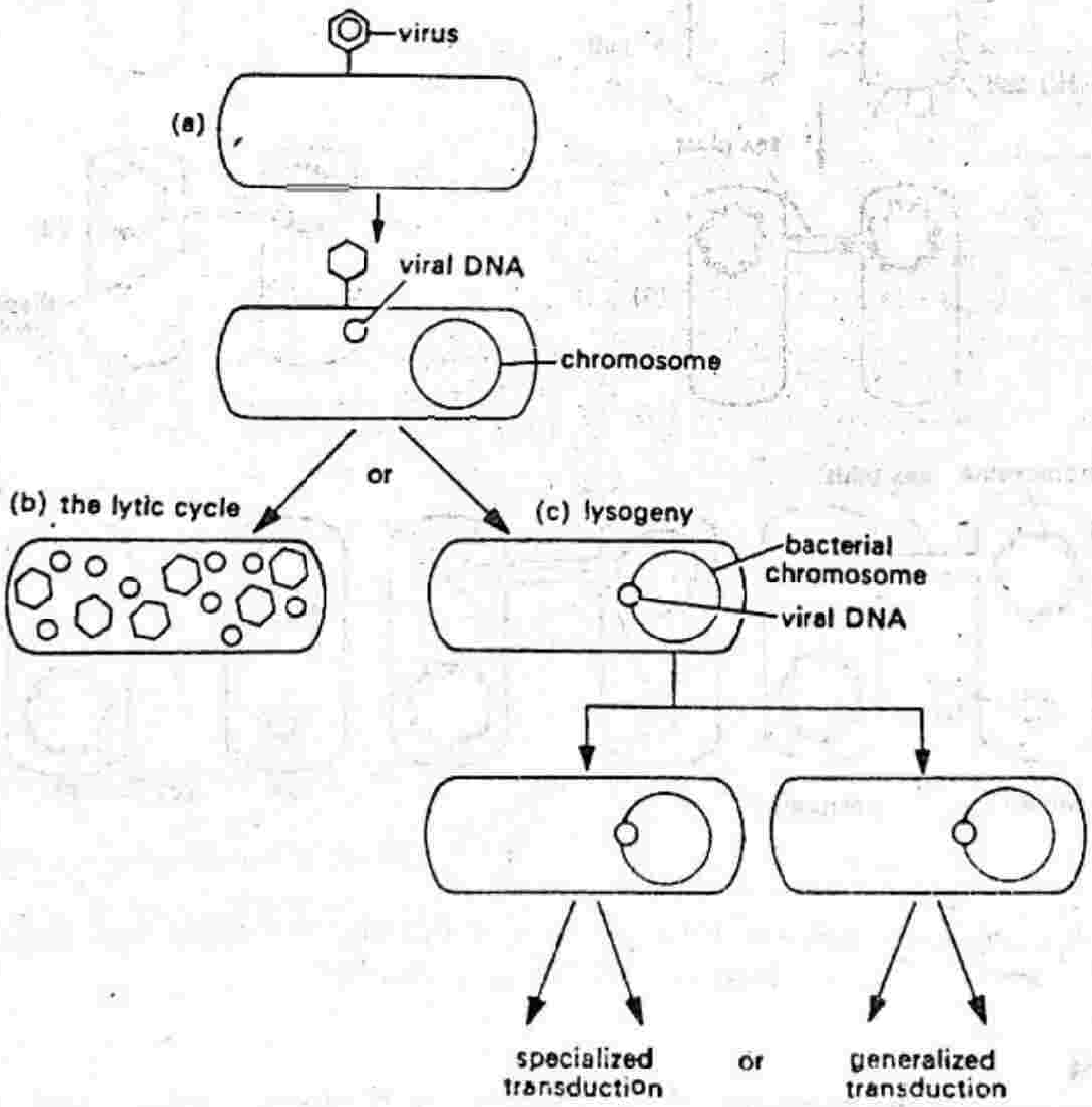


Fig. 2.9: Transduction in bacteria.

Later, they carried U-tube experiment. They placed nutritional mutants in each arm of the tube and separated them by a fine glass filter that does not allow the bacteria to pass through it. However, the recombinants were found even then. This rules out conjugation. Zinder and Lederberg suggested that some filterable agent is responsible for exchange of genetic material. It was also observed that this agent is not destroyed by Dnase (deoxyribonuclease). This suggests absence of transformation. It was soon found that this filterable agent is a phage virus or bacteriophage. Later, the phenomenon was also observed in *E. coli*.

Mechanism of Transduction

During infection the bacteriophage or phage virus attaches itself to surface of the bacterial cell and injects its DNA into the cell. The viral DNA directs the synthesis of viral proteins and new phage particles are assembled in the cell. The cell wall of bacterial cell bursts and the phages are released. This is called lytic cycle. However, some viruses incorporate their DNA into bacterial chromosome after infection. These are called temperate viruses and the recombinant DNA is known as prophage. Such bacteria are called lysogenic bacteria. The viral DNA replicates alongwith bacterial chromosome normally, however under certain conditions it destroys the bacterial cell, and the prophages are released. When these prophages infect other bacteria, they transfers donor bacterial DNA to recipient bacterial DNA. Thus, phage virus serves as a vector between donor and recipient bacteria.

Patterns of Transduction

Transduction occurs in two patterns:

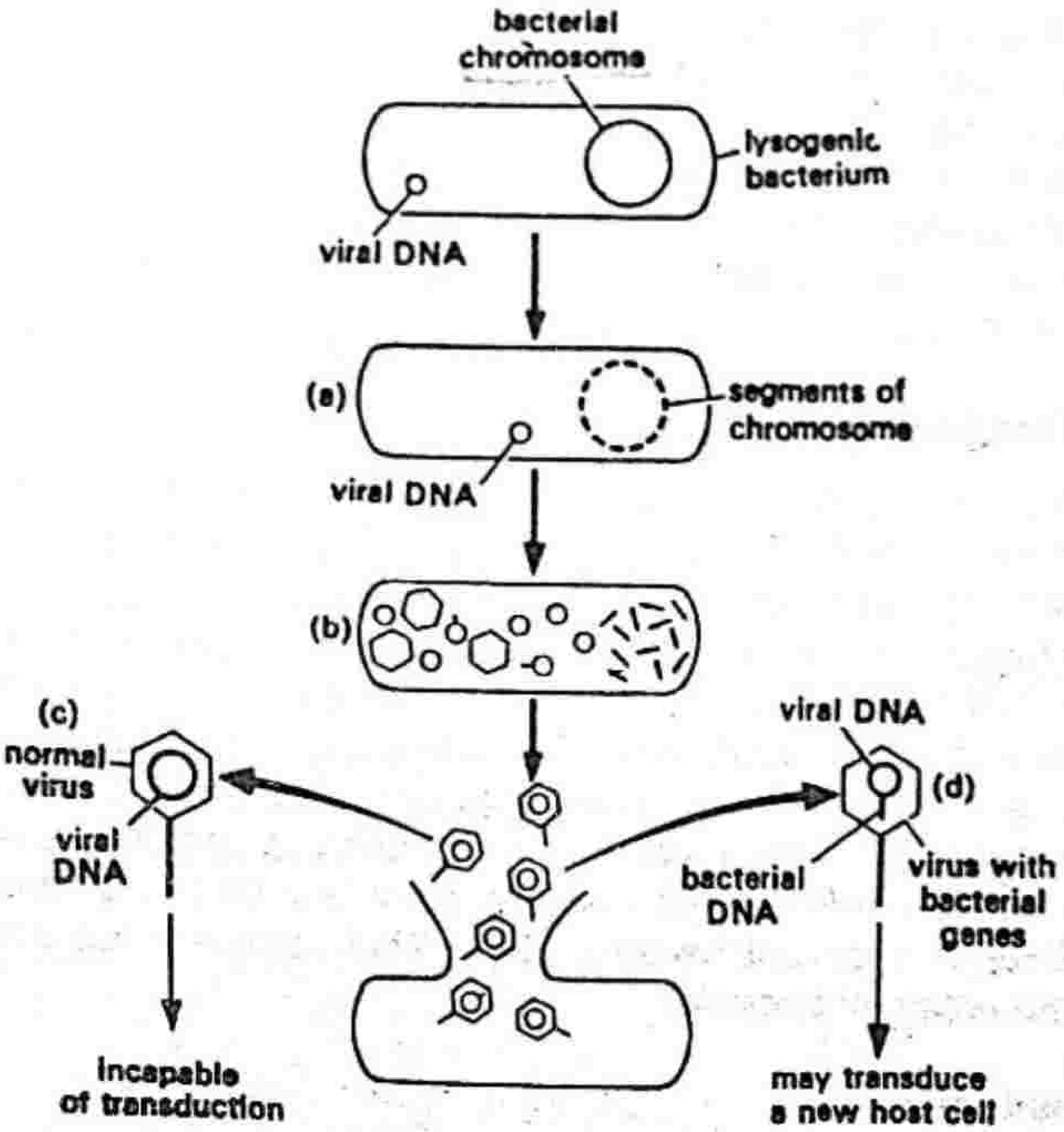
i.Generalized Transduction

If all fragments of bacterial DNA have a chance to enter a transducing phage, the process is called generalized transduction.

The viral enzymes hydrolyze bacterial chromosome into many small pieces and any part of the bacterial chromosome may be incorporated into the phage head during phage assembly. It is usually not associated with any viral DNA. A large population of transduced phages carrying different fragments of the bacterial chromosome are produced. A small proportion of the phages carry only bacterial DNA. When these abnormal phage particles infect a bacterium the donor DNA is integrated into chromosome of the recipient cell.

ii.Specialized Transduction

In this type of transduction the temperate phages can transfer only a few restricted genes of bacterial chromosome that are adjacent to the prophage in the bacterial chromosome. Therefore, the process is also called restricted transduction. It occurs when a bacteriophage genome, after becoming integrated as prophage in the DNA of the host bacterium, again becomes free upon induction and takes with it into the phage head a small adjacent piece of the bacterial chromosome. When such a phage infects a cell, it carries with it the group of bacterial genes that has become part of it. Such genes can recombine with the homologous DNA of the infected cell. The specialized transduction is studied best in phage lambda of E. coli.



Q:5

Fig. 2.10: Generalized transduction.

NUTRITION IN BACTERIA

The bacteria can be classified into two nutritional categories on the basis of their nutritional requirements: the autotrophic and heterotrophic bacteria.

1.Autotrophic Bacteria

The bacteria that are able to synthesize organic compounds necessary for their survival from simple inorganic substances are called autotrophic bacteria. They obtain carbon from inorganic compounds, mostly from carbon dioxide.

The autotrophic bacteria are further classified into: photoautotrophs and chemoautotrophs.

light→chlorophyll)

i.Photoautotrophs (Photosythetic Bacteria).

(The bacteria in which the energy source is light are called photoautotrophs. These bacteria possess chlorophyll, therefore these are able to manufacture their own food. These are also called photosynthetic bacteria.) The bacterial-chlorophyll is similar in structure to the chlorophyll found in plant cells, however it is not contained in the chloroplasts. It is dispersed throughout the cytoplasm of the bacteria. Photosynthetic bacteria use sunlight as source of energy. The hydrogen source is H_2S (hydrogen sulphide) instead of water in these bacteria, and sulphur is released during the process.

(ii) Ans:
Equation

$$2H_2S + CO_2 \xrightarrow[\text{bacteriochlorophyll}]{\text{light}} [CH_2O] + 2S + H_2O$$

The photoautotrophs may be:

a. **Purple Sulphur Bacteria:** The bacteria which use sulphur compounds as source of electrons and protons, for example *Chromatiumokenii*.

$$2CO_2 + 5H_2O + Na_2S_2O_3 \longrightarrow 2(CH_2O) + 2H_2 + NHSO_2 + \text{energy}$$

b. **Green Sulphur Bacteria:** These bacteria use H_2S as source of electrons and protons, for example *Chlorobium and Chlorobacterium*.

$$2H_2S + CO_2 \longrightarrow [CH_2O] + 2S + H_2O$$

c. **Purple Non-Sulphur Bacteria:** These bacteria use organic compounds as source of electrons and protons, for example *Rhodospirullumrubrum* which use propyl alcohol.

$$2CH_3CHOHCH_3 \longrightarrow CH_2O + CH_3COCH_3 + H_2O$$

ii. Chemoautotrophs

The bacteria which derive energy from oxidation of inorganic chemical substances during respiration are called chemoautotrophs. These bacteria play important roles in the biosphere, principally in maintaining soil fertility through their activities in the nitrogen cycle.

Chemosynthetic bacteria are further divided into:

a. **Nitrifying Bacteria:** These bacteria inhabit the soil and oxidize ammonia into nitrites, for example Nitrosomonas; or nitrites into nitrates for example *Nitrobacter*. The energy released is used by these bacteria in synthesis of food.

12+13

Energy

$$2NH_3 + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2HNO_2 + 2H_2O + (158\ \text{Kcals})$$

Nitrite

$$2HNO_2 + O_2 \xrightarrow{\text{Nitrobacter}} 2HNO_3 + 43\ \text{Kcals}$$

Nitrate

b. **Iron Bacteria:** These bacteria are commonly present in iron-rich water. These bacteria oxidize ferrous compounds into ferric compounds and obtain energy. Common examples are *Leptothrix*, *Cladothrix* and *Ferrobacillus*.

$$2Fe(HCO_3)_2 + H_2O + O \longrightarrow 2Fe(OH)_3 + 4CO_2 + 29\ \text{Kcals}$$

$$4FeCO_3 + O_2 + 6H_2O \longrightarrow 4Fe(OH_3) + 4CO_2 + 81\ \text{Kcals}$$

c. **Sulphur Bacteria:** These bacteria are found in hot springs containing hydrogen sulphide. These oxidise metallic sulphide to sulphur to obtain energy. The common examples are *Beggiatoa and Thiothrix*.

d. **Hydrogen Bacteria:** These bacteria grow in organic media containing hydrogen, carbon dioxide and oxygen and can oxidise hydrogen with the liberation of energy. These include *Bacillus panctotrophus*.

$$2H_2 + O_2 \longrightarrow 2H_2O + 137\ \text{Kcals}$$

$$2H_2 + CO_2 \longrightarrow (CH_2O) + H_2O + 118\ \text{Kcals}$$

20 M

e. **Methane Bacteria:** These bacteria oxidise methane to carbon dioxide. Methane is the source of both carbon as well as energy to these bacteria, for example *Methanosomonas*.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy}$$

* 2.Heterotrophic Bacteria *

The bacteria that obtain their energy from organic compounds made by other organisms are called heterotrophic bacteria. These bacteria are unable to prepare their food and they get their food from other sources.

Most bacteria are heterotrophic and can be classified into:

Dead

i.Saprotrophic Bacteria

The bacteria obtain their food from dead and decaying matter, for example humus. These bacteria are also called decomposers These bacteria have their own enzyme system. They secrete enzymes which digest complex organic compounds into simpler substances. These substances are absorbed by the bacteria and used as source of energy.

1/1

ii.Parasitic Bacteria

These bacteria are heterotrophic but lack their own enzyme system, therefore these cannot synthesize food from simple organic substances. They depend upon enzymes of other living organisms (hosts) to synthesize food for their growth. Many parasitic bacteria cause disease. These bacteria are called pathogens or virulent, for example *Pneumococcus* causing pneumonia.

2/2 دونوں کو فائدہ ← (Relationship:-)

iii.Symbiotic Bacteria

(13)

There are certain bacteria, for example *Rhizobium radicicola*, which form symbiotic association with roots of leguminous plants. They form nodules, fix atmospheric nitrogen, and supply nitrogenous compounds to the plants and get food in turn from plants.

Relationship

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Q:6 BIOLOGICAL IMPORTANCE OF BACTERIA

Bacteria are important for their natural roles in the biosphere, for example their role in rhizosphere, nodulation, and nitrogen cycling.

1.Role of Bacteria in Rhizosphere

[contact of soil and root.] ✓

The region where the soil and roots make contact is called the rhizosphere. The rhizosphere is a complex biological system in which the bacterial population is considerably higher on and around the roots than that of root-free soil. The bacterial growth is enhanced by nutrients released from the plant tissue, for example, amino acids, vitamins, etc.

(small ball like structures on roots → [illegible])

2.Role of Bacteria in Nodulation — Symbiotic Nitrogen-Fixation

The nodules are swellings in the roots. These are composed of cells that contain nitrogen-fixing bacteria. The nodules are characteristic of the members of Leguminosae and are built-in source of fixed nitrogen. The bacteria supply the legume with fixed nitrogen, and the plants provide the bacteria with carbohydrates and other organic compounds.

3.Role of Bacteria in Nitrogen Cycling

Of all mineral elements, nitrogen most often limits the growth of plants and the crop yield. The plants require nitrogen synthesis of proteins, nucleic acids, and other important organic molecules. However, the plants are unable to absorb gaseous N_2. It must first be converted to ammonium (NH_4^+) or nitrate (NO_3^-) before the plants can absorb it. The conversion of molecular nitrogen into ammonia or nitrate is called nitrogen fixation.

Certain bacteria called nitrogen-fixing bacteria are able to fix atmospheric nitrogen. These bacteria like *Rhizobium leguminosarum*may live freely in the soil or associated with roots of the plants.

The nitrogen-fixing bacteria may be:

i. **Non-symbiotic:**These are bacteria that live freely and independently in the soil. The common examples are *Clostridium and Azotobacter spp.*

ii. **Symbiotic:**These are bacteria that live in roots of plants, for example in root nodules of legumes. These include *Rhizobium* spp.

[illegible] (خشک پھلی کی شکل کا پھل)

4.Role of Bacteria in Decomposition and Nutrient Recycling

Saprotrophic bacteria alongwith fungi decompose dead organic matter and form partially decomposed organic matter, the humus. The formation of humus is called humification. These are taken up by plants once again to build organic compounds. This is known as nutrient recycling.

partially decayed matter

Q: 7 GENERAL ECONOMIC IMPORTANCE OF BACTERIA

The bacteria can be deliberately exploited by humans in a number of beneficial ways. However, some bacteria play harmful roles, for example they cause disease and spoil food. Thus economic importance of bacteria include both their useful and harmful aspects.

✓ USEFUL BACTERIA

Most bacteria are beneficial to mankind and play some economically important roles. Some of these useful roles are as under.

1.Biotechnology and Bacteria

✓ Def:- Biotechnology is defined as application of organisms such as bacteria, fungi and algae to the manufacturing and service industries. These include: چھاچھ سے نکالا ہوا / مکھن دہی

i. Fermentation processes such as brewing, baking, cheese and butter manufacturing; chemical manufacturing such as ethanol, acetone, organic acids, enzymes, perfumes, etc.

ii. Pharmaceuticals like antibiotics, vaccines and steroids. [illegible]

iii. Energy in the form of biogas. CH_4 gas (Methane)

iv. Food products such as beverages, dairy products, amino acids, proteins.

v. Agriculture industry like animal feed, pesticides, nitrogen-fixation, plant cell and tissue culture. گوڈنا [illegible]

vi. Microbial mining, e. g., copper extraction.

The bacteria and other microorganisms are cultured in containers and then used to bring these processes.

2.Genetic Engineering and Bacteria

Genetic engineering is manipulation of genes. It is also called recombinant DNA technology. In genetic engineering, pieces of DNA (genes) are introduced into a host by means of a carrier (vector) system. The foreign DNA becomes a permanent feature of the host, being replicated and passed on to daughter cells along with the rest of its DNA. Bacterial cells are transformed and used in production of commercially important products. The examples are production of human insulin.

3.Role in Fiber Retting

(Plants)

Bacterial population especially that of *Clostridium butyclicum* are used to separate fibers of jute, hemp, flax, etc. The plants are immersed in water and when they swell, inoculated with bacteria which hydrolyze pectic substance of the cell walls and separate the fibers. These separated fibers are used to make ropes and sacks.

4.Role in Digestion

Some bacteria living in gut of cattles, horses, and other herbivores secrete enzyme cellulase that help in digestion cellulose contents of cell wall. Cellulose is the major source of energy in these animals.

Recombiment DNA => include forign DNA

5.Vitamins Synthesis

Escherichia coli living in human colon synthesize vitamin B and release it for human use. Similarly *Clostridiumbutylicum* is used for commercial preparation of riboflavin, a vitamin B.

6.Role in Waste Disposal

(کیچڑ - گارا - دلدل)

گندگی/گندہ پانی

B

Aerobic and anaerobic bacteria are used to decompose sewage wastes. They break down organic matter to harmless, soluble sludge in settling tanks. The methane gas produced is used as energy source. Similarly toxic chemicals synthesized by living organisms and those present in the pesticides are disposed with the help of bacteria. *Pseudomonas putida* has been created by using genetic engineering technique can break down octane, xylene, and camphor.

✓HARMFUL BACTERIA

Some bacteria are harmful and act either as disease-causing agents (pathogens) both in plants and animals, or play a role in food spoilage.

1.Bacteria as Pathogens — Agents of Disease

Organisms which cause disease are called pathogens. Some bacteria are pathogenic and cause diseases both in animals and plants. However, pathogenic bacteria more commonly affect animals than plants.

درختوں کی تباہ کن بیماری

جس میں پتے جھلس جاتے ہیں/اندر سے کالے اور [illegible]

(15)

i.Plant Diseases

species

[illegible] About 200 spp of bacteria are known to cause diseases in plants. These include crown galls of fruit trees (*Agrobacterium tumefaciens*), fire blight of apples and pears (*Erwiniaamuylovorum*), citrus canker (*Xanthomonascitri*), black rot of cabbage (*Xanthomonascampestris*), potato scab (*Streptomyces scrabies*), and leaf blight of rice (*Xanthomonasoryzae*).

داغ لگا نشان

ii.Animal Diseases

سور

Important diseases of animals include food poisoning of pigs and poultry (*Salmonella*), anthrax (*Bacillus anthracis*), and black leg (*Clostridium chauvei*). Human bacterial diseases include penumonia (*Diplococcuspenumonie*), wound infections (*Streptomyces scabies*), stomach trouble (*Pseudomonas coli*), food poisoning (*Clostridium spp*), influenza (*Hemophilous influenza*), typhoid (*Eberthellaspp*), tuberculosis (*Mycobacterium tuberculosis*), etc. (معیادی بخار)

(T.B.) [illegible] بیماری] (دق کی بیماری)

2.Bacteria and Food Spoilage

{decompose → dead organism → partially decompose}

Saprotrophic bacteria attack and decompose organic matter. This characteristics has posed problem to mankind as food such as stored grains, meat, fish, vegetable and fruits are attacked by saprotrophic bacteria and spoiled. Similarly milk and milk products are easily contaminated by bacteria and spoiled.

AN OUTLINE OF LYNN MARGULIS AND KARLEN SCHWARTZ CLASSIFICATION

Lynn Marguilus and Karlen Schwartz proposed a useful classification of bacteria on the basis of form, motility, metabolism, and ecological roles of the bacteria. They classified bacteria into following phyla.

+ Shape .

1.Archaebacteria

The bacteria with distinctive membranes, unusual cell walls that lack muramic acid. They contain ribosomes similar to those in eukaryotes. Methanogens,(methane producing bacteria, are most common phylum members

2.Omnibacteria

The phylum includes rod-shaped and comma-shaped (vibrios), heterotrophic, Gram-negative bacteria. Most of these are pathogens. They are usually aerobic but continue to function using nitrogenous compounds.

Bacteria which cause disease in plants and animals.

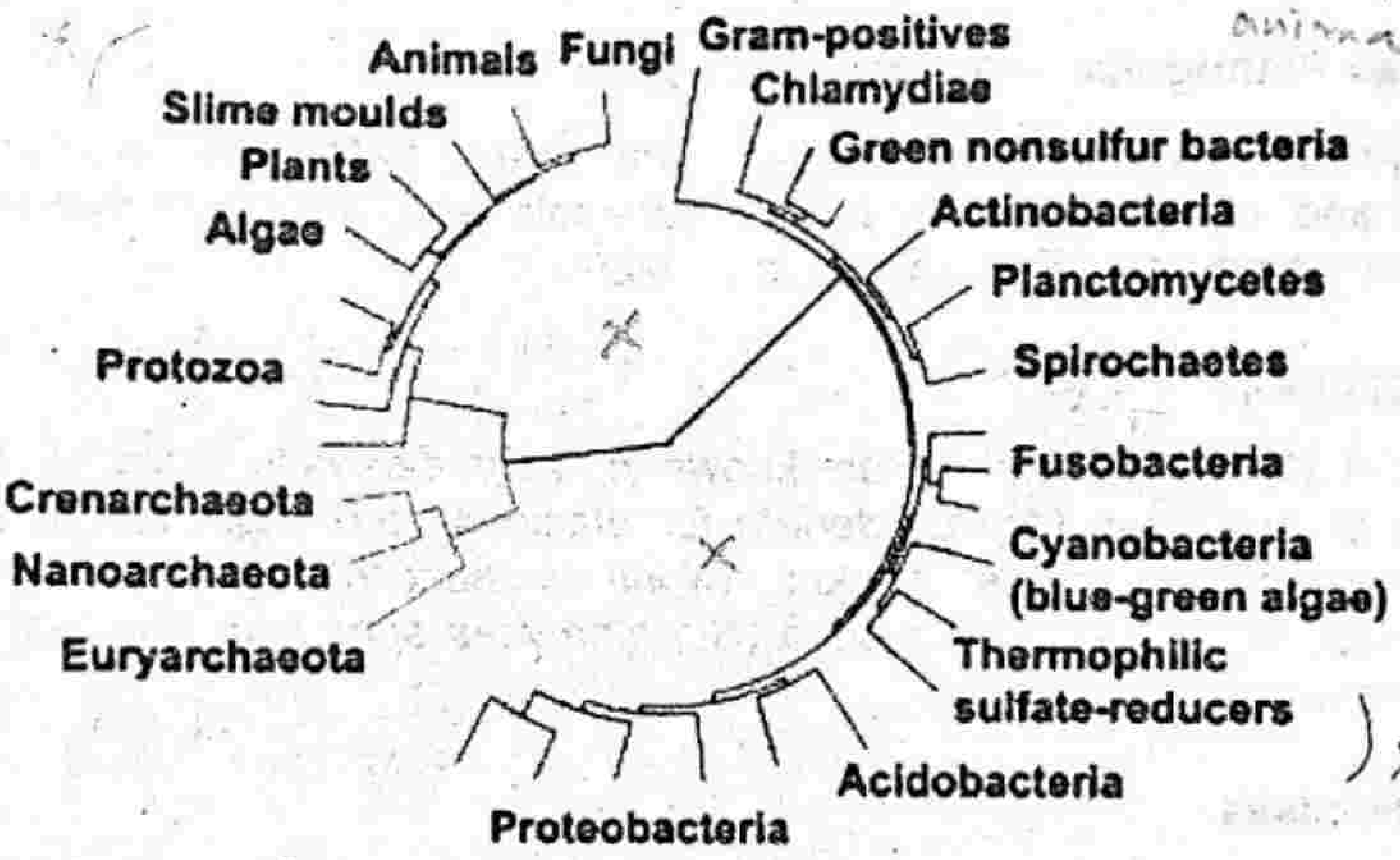


Fig 2.11: Phylogenetic tree showing the diversity of bacteria, compared to other organisms.

3.Cyanobacteria

Photosynthetic bacteria that contain ① chlorophyll a, ② carotenoids and ③ blue and red water-soluble (phycobilins.) They are able to fix atmospheric nitrogen and are photosynthetic members of lichens.

4.Chloroxybacteria

The phylum consists of a single genus of photosynthetic bacteria, Prochloron. It contains chlorophyll a and b that resembles those of eukaryotic algae and plants. It is capable of fixing nitrogen

سیدھی سیدھی بات

5.Mycoplasmas and Spiroplasmas

These phyla include tiny bacteria that lack cell walls. The cells are bounded by a triple-layered membrane composed of lipids.

6.Spirochaetes

one ?

These are long spirilla in which the flagella are inserted beneath the outer lipoprotein membrane of their Gram-negative outer cell wall.

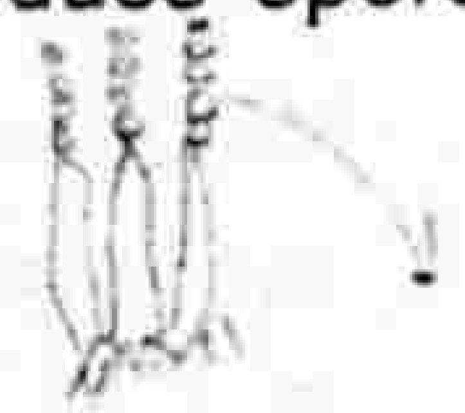
7.Pseudomonas

They are straight or curved rods that have one or several flagella at one end.

8.Actinomycetes

Like (Fungi) → without leaves, stem & root.

It is a distinctive phylum of bacteria that are sometimes mistaken for fungi because of their filamentous growth form. Members of the phylum produce spores by division of their terminal branchletes in the form of chains.



9.Myxobacteria

(ریست) سیدھے

Myxobacteria are gliding bacteria, some of which form upright spore-bearing structures. They are unicellular rods that aggregate in a slimy mass which they secrete.

10.Nitrogen-Fixing Aerobic Bacteria

This is a phylum of great economic importance. All the members are Gram-negative and most are flagellated. It includes nitrogen-fixing free-living or nodulated bacteria, for example *Azotobacter, Clostridium, Rhizobium*, etc.

11.Chemoautotrophic Bacteria

Chemoautotrophs appear to be ancient and primitive phylum of bacteria. These bacteria depend on chemical source of energy such as the reduced gases ammonia (NH_3), methane (CH_4), or hydrogen sulphide (H_2S). The most common members are *Nitrosomonas, Nitrobacter*, etc.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Describe types of bacteria?
2. What are flagella? Classify bacteria on basis of flagella.
3. What is Gram positive and Gram negative bacteria?
4. What is plasmid?
5. Enlist different stages of bacterial growth.
6. What is binary fission.
7. How endospore is formed in bacteria?
8. Define conjugation in bacteria.
9. What is sex factor?
10. Define transduction?
11. What are sulpher bacteria?
12. What is the role of bacteria in nitrogen cycle?
13. Give two importance of bacteria.
14. What are archaeobacteria?
15. Enlist bacterial plant diseases?

✓ B. Long Questions

1. Describe structure of bacteria?
2. Write note on growth of bacteria.
3. Write note on transformation.
4. Define transduction? Write an essay on transduction.
5. Write a note on nutrition in bacteria.
6. What are the biological importance of bacteria.
7. Give economic importance of bacteria in detail.

SECTION IV

CYANOBACTERIA

Chapter 3

CYANOBACTERIA

The name Cyanophyta (Gr. kyanos=blue + phyta= plants) has recently been adopted for this division. The division was named Myxophyta (Gr. myxa=slime + phyton=a plant) previously. It includes a single class Cyanophyceae. Most of the characteristics possessed by the members of this division are similar to those present in the bacteria, therefore these are placed alongwith bacteria in Kingdom: Monera. However, these are considered nearer to algae because of presence of chlorophyll-a and liberation of O_2, similar to other algal groups. They are commonly called blue-green algae because of dominant blue photosynthetic pigment in their chromatophores.

GENERAL CHARECTERS OF CYANOPHYTA

Habitat

1. The members of this class are commonly known as blue green algae.
2. They are found in fresh water, ponds, ditches, drains and moist soils.
3. The terrestrial species form layers on moist, shaded bare soils or rocks.
4. A few species are endophytes, i. e., live in the cavities of other plants, usually bryophytes, for example *Nostoc* is found in the thallus of *Anthoceros* and Anabaena in the roots of certain cycads.
5. They are algal partners of lichens. Many grow in waters of hot springs and form rock-like strata.
6. Only few forms are marine.
7. They are also found in hot water streams.

Cell structure

1. Only few forms are unicellular, while majority of them are multicellular and some are members forms colonies. The cells are embedded in gelatinous sheath.
2. A single row of cell in each colony is called as trichome and trichome with mucilage form the filament.
3. Plastids are absent. The pigments are found in he cytoplasm called as chromatoplasm.
4. Cells are blue in color due to the presence of phycocyanine (a blue pigment), chlorophyll, carotene and phycoerytherin.
5. The cells are without any mitochondria, endoplasmic reticulum and Golgi bodies.
6. A definite nucleus is absent and nuclear material is present as central body, which lacks nucleus.

Reserve food material

1. Reserve food is in the form of sugars and glycogens.Minute oil drops are also present.
2. A proteneious material cyanophycin is also found as reserve food material.
3. Some members such as Anabaena can fix nitrogen into nitrates.

Reproduction

1. **Hormogones:** Small parts of filament detached either by direct breaking of by the formation of special disk called as hormogones.
2. **Heterocyst:** Special large cells with thick walls called as heterocyst is present in the filament. The filament is detached at this point.
3. **Hormospores:** These are apical portion of the trichome in which the cells become enlarged and thick walled. On separation these hormospores produced new filaments.
4. **Akinetes:** When the vegetative cell along with the original cell wall is transformed into a spore.
5. **Endospores:** when the vegetative cell give rise to several spores after the division of protoplast.
6. Motile reproductive bodies are entirely absent. There is no sexual reproduction present in the members of cyanophyta.
7. Sexual reproduction is entirely absent in this class.

Examples

Anabaena, Nostoc, Oscillatoria etc.

Economic Importance of Blue-green Algae

The most important economic aspects of blue-green algae is their role in nitrogen fixation and soil building.

Role in Nitrogen Fixation

Generally algae utilize nitrates, ammonium salts and organic nitrogen as main source of nitrogen. Some species utilize ammonium ions and others nitrites. However, the members of Cyanophyta are capable of absorbing and fixing atmospheric nitrogen. This is called nitrogen fixation. The nitrogen is incorporated into the metabolic pathways as ammonia which is utilized in the synthesis of amino acids and proteins. The majority of the blue-green algae capable of fixing nitrogen have heterocysts in their filaments and belong to Chroococcales, Nostacales and Stigonematales. A few non-heterocyst species like *Oscillatoria princeps, Chlorogloea fristchii* and *Gloeocapsa sp* have also been reported to fix atmospheric nitrogen.

Role in Soil Building

The members of Cyanophyceae play an important role in preventing erosion, reclamation of saline soils, and improving aeration of the soil. Therefore, these play an important role in soil building.

i. Some members of blue-green algae such as *Chroococcus, Phormidium,* e.t.c, form thick mats on soil surface, therefore act as soil binding agents. They prevent erosion especially in disturbed or burnt soils. These also increase water absorbing capacity of the soil.

ii. The members of *Cyanophyceae, e. g., Nostoc, Scytonema* and *Anabaena*, form thick stratum on the surface of saline soil during rainy seasons. They help to reduce the pH of saline soils and increase water holding capacity of such soils.

iii. The rice fields are inoculated with Nostoc and Anabaena species. This results in promoting the yield of rice crop. The protein contents of the plants growing in such fields increase.

Harmful Aspects of Blue-green Algae

In addition to beneficial roles, the blue-greens produce certain harmful roles as well. These include:

i. **Death to Fishes:** *Microcystis aeruginosa* found in fish ponds produce a toxic compound poisonous to fish. Similarly blooming species cause suffocation to fishes by choking their gills.

ii. **Death to Animals:** A few blue-greens such as *Microcystis, Anabaena, Nodularia, Gloeotrichia* spp produce toxins causing deaths to animals like horses, cattle, sheep, etc.

iii. **Water Pollution:** Blue-green algae especially *Oscillatoria, Anabaena, Microcystis* spp grow immensely in storage water and pollute it. Their decomposition produce a bad odour and cause interference in water filtration.

Affinities of Cyanophyceae

The members of Cyanophyceae are more near the bacteria than algae. The resemble bacteria in their prokaryotic cell structure, physiology and reproduction. Vilhelm placed blue-green algae in a group Archaeophyta alongwith bacteria. Fott classified blue-green algae in Prokaryonta (prokaryotes). Chadefausd (1960) recognized two groups among prokaryotes: the Cyanoschizophyta (blue-green algae) and Bacertioschizophyta (bacteria). He suggested that these two groups are linked together by transitional forms and blue-green algae are more primitive to bacteria. But, since the word algae is used for non-vascular green cryptogams, therefore the blue-green algae is included in algae. They exhibit some common characters with algae especially Rhodophyceae.

Affinities with Bacteria

The blue-green algae exhibits following characteristics common with bacteria.

i. The presence of mucilaginous sheath around the cells.

ii. The construction and chemical nature of cell wall is almost similar in both groups.

iii. Both lack well organized nucleus and plastids. The nuclear material occupies centre of the cell or distributed throughout the cell cytoplasm.

iv. The members of both bacteria and blue-green algae are capable of nitrogen fixation.

v. The reproduction is by fission or resting cells (akinetes).

vi. The true sexual reproduction is absent in both groups, however parasexual phenomena such as transduction are reported in blue-green algae.

vii. The members of both groups are characterized by presence of specific pigments, for example phycobilins in blue-green algae and bacteriochlorophylls in bacteria.

viii. Both are pioneers to colonize lifeless regions of volcanic origins.

Affinities with Red Algae

Blue-green algae exhibit the following common characters with red algae.

i. The principal constituents of mucilaginous sheaths are galactose, uronic acid, glucose and xylose in both cases.

ii. The presence of dominant phycobilin pigments (phycocyanin and phycoerythrin) in the members of both the groups.

iii. The reserve food in blue-green algae (Cyanophycean starch) resemble Floridean starch found in red algae.

iv. The thylakoids containing photosynthetic pigments occur singly and widely separated in both groups.

v. The members of both groups are characterized by absence of motile cells.

However, the red algae differ from blue-green algae in that:

i. They possess true nuclei.

ii. The presence of cellulose and carbohydrates in cell walls.

iii. The presence of true sexual reproduction.

iv. The presence of eukaryotic organelle like mitochondria, Golgi complex, endoplasmic reticulum, etc.

NOSTOC

C.W = cellulos

sugar, glcogen, protein

Taxonomic Position

Kingdom:	Bacteria	King
Phylum:	Cyanobacteria	Play
Class:	Cyanophyceae	Cards
Order:	Nostocales	on orderly
Family:	Nostocaceae	fine on
Genus:	*Nostoc*	Fine Green Sand

Occurrence

Nostoc is common in fresh water ponds. The large colonies found free floating as small circular balls. It may be attached to the submerged plants (Nostoc can be found in soil, on moist rocks, at the bottom of lakes and springs (both fresh- and saltwater), and rarely in marine habitats) It may also grow symbiotically within the tissues of plants, such as hornworts, providing nitrogen to its host through the action of terminally differentiated cells known as heterocysts. It may found as algal component of certain lichens.

PLANT BODY

Colony

Many twisted trichomes aggregate in a gelatinous matrix to form a ball-like globular or ellipsoidal colony which ranges from greenish to bluish-green in colour. The colony is externally bounded by a tough, firm and pellicle-like membrane which provides a definite shape to the colony.

Cell Structure

The cell is typical prokaryotic type. The cells are without any mitochondria, endoplasmic reticulum and Golgi bodies.

It has following demarcations

Cell wall

The protoplast is surrounded by cell wall composed of cellulose.

Pigments

Plastids are absent. The pigments are found in he cytoplasm called as chromatoplasm. Cells are blue in color due to the presence of phycocyanine ① (a blue pigment), chlorophyll ②, carotene ③ and phycoerythrin ④.

Nucleoplasm

A definite nucleus is absent and nuclear material is present as central body, which lacks nucleolus.

Reserve food material

Reserve food is in the form of sugars and glycogens and proteinaceous material cyanophycin

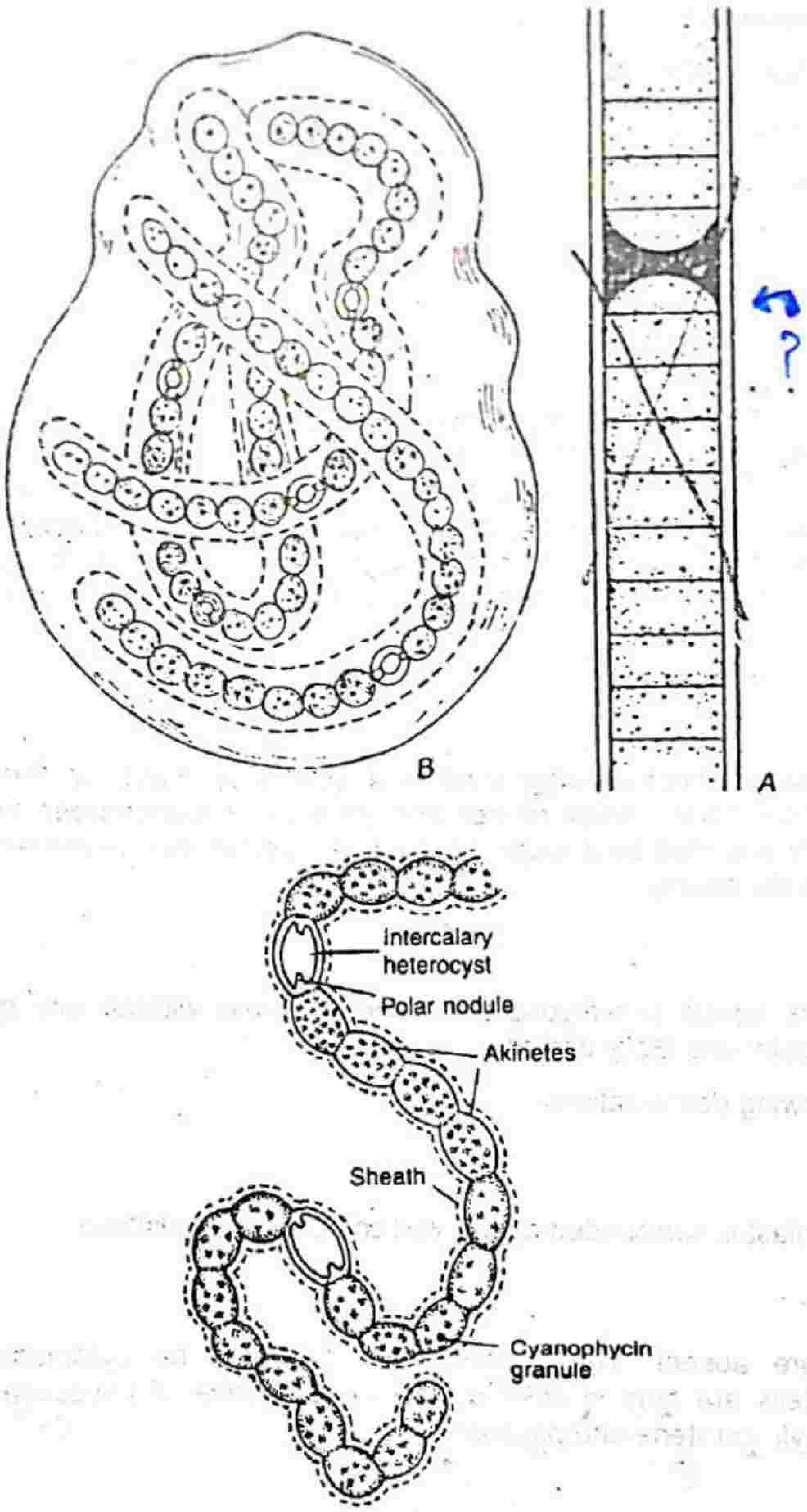


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Fig. 3.1: Nostoc — Morphology of a cell and colony.

Reproduction

The usual methods of reproduction in Nostoc are vegetative and asexual reproduction. The sexual reproduction by union of gametes is absent.

The reproduction usually takes place by the following methods in the Nostoc.

i.Colony Fragmentation

The colony breaks down into two or more fragments accidently or due to some physiological reason. Each fragment grows into a new colony.

ii.Hormogonia

This is the most common method of reproduction in Nostoc. The filament is broken down into a number of short-length pieces, the hormogonia due to development of heterocysts or by the death of ordinary vegetative cells. These hormogonia come out of the colony by piercing the colonial sheath. Each develops its own sheath and then aggregate to form a new colony.

iii.Akinetes

Akinetes or resting spores are formed in many species of Nostoc. A vegetative cell enlarges, secretes a thick wall around it, and stores quite a large amount of food in it to function as an akinete. The akinetes are usually present adjacent to the heterocysts singly or in chains. These help the plant to overcome unfavourable conditions. At the onset of favourable conditions the akinetes release their contents through a pore which germinate into a new filament.

iv.Arthrospores

The akinetes which are resting spores are called as arthrospores.

v.Endospores

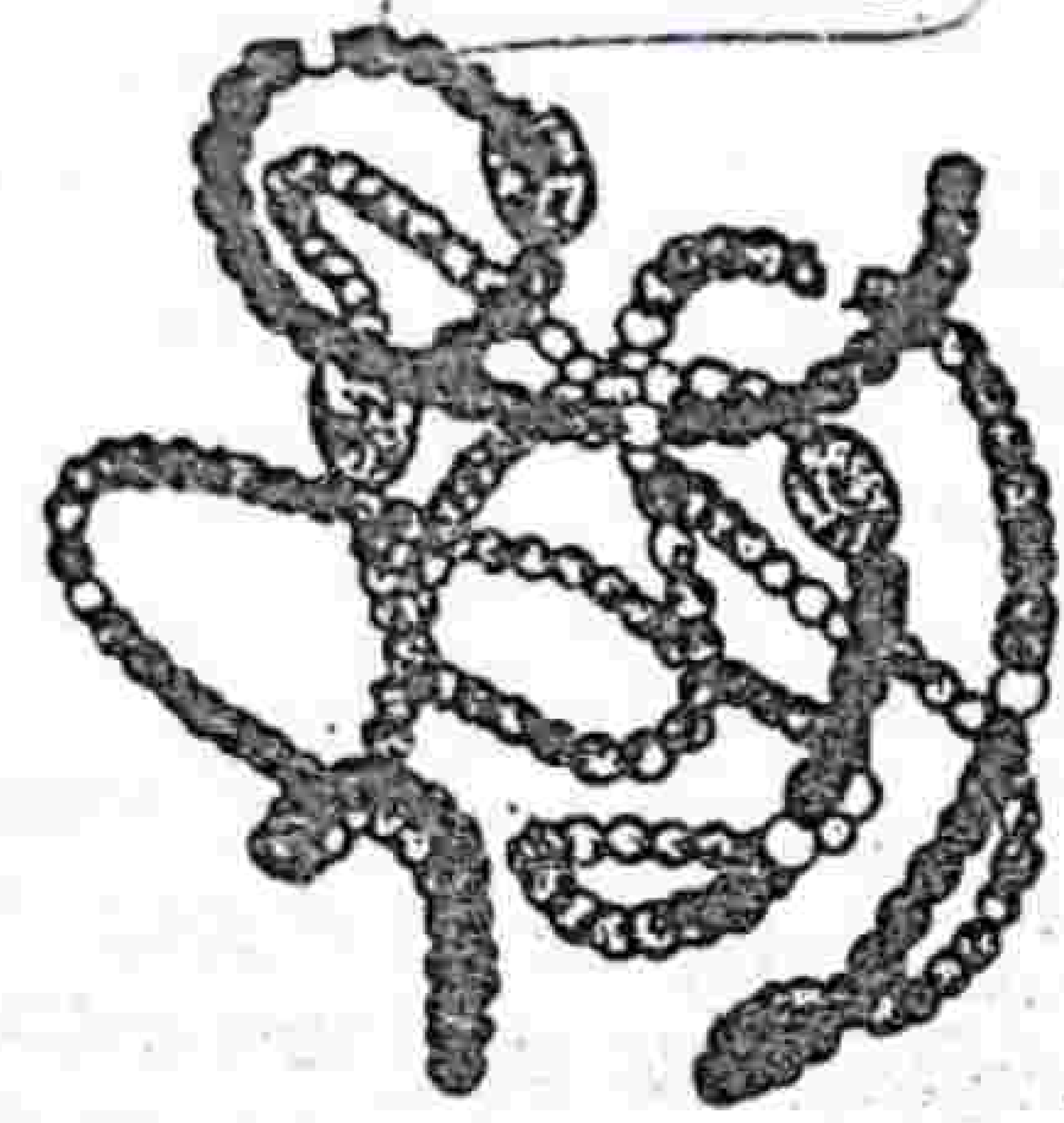
In some species, e. g., *Nostoc microscopium* and *N. commune*, heterocyst contents divide to produce endospores. These spores are released and develop into new filaments.

Come ANABAENA

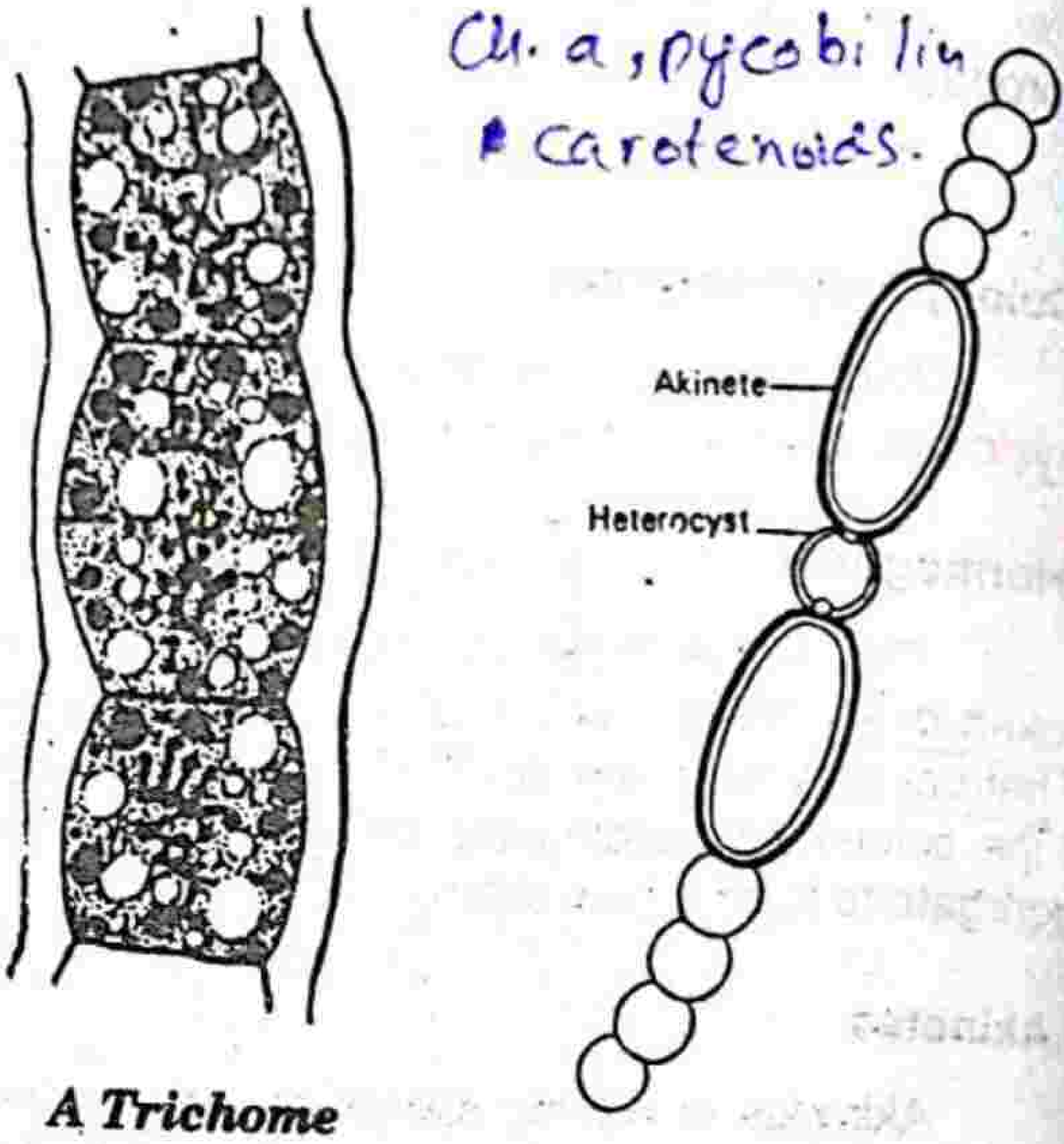
C·W = amino acid peptides
Ch. a, pycobilin & carotenoids.

Taxonomic Position

Kingdom:	Bacteria
Phylum:	Cyanobacteria
Class:	Cyanophyceae
Order:	Nostocales
Family:	Nostocaceae
Genus:	*Anabaena*



A Colony



A Trichome

Fig. 3.2: Morphology of cell and colony

Occurrence

Anabaena (Gr. Anabaniein=to arise) is a filamentous blue green alga. The genus contains both planktonic species and some that form coatings on other aquatic vegetation. A few species are endophytic and grow in cavities between the leaves of the water fern *Azolla* and roots of the cycads. It is widespread in bodies of fresh and salt waters. It occurs frequently as dominant organism in water blooms. Anabaena species are characterized by presence of heterocysts and akinetes in their filaments.

PLANT BODY

The thallus comprises of unbranched filaments in which the cells are joined end to end. The filaments arise as a result of restriction of cell divisions to only one direction. A single row of the cells in a filamentous colony is a trichome. A filament may contains one or more trichome are thick walled and modified into akinetes and heterocysts. Movements of the filament by waving of the terminal portion of a trichome have been reported.

Cell Structure

The vegetative cell is prokaryotic and is characterized by absence of membrane-bound plastids, nuclei, large central vacuole, mitochondria, Golgi apparatus and endoplasmic reticulum.

Cell wall

The protoplast is surrounded by cell wallformed of amino acid peptides.

Chromoplasm

The chromplosm contains flattened sacs, thylakiods, in which the photosynthetic pigments are located. The thylakoids are not segregated from cytoplasm by a membrane. The photosynthetic pigments are characteristics phycobilins (phycocynanin and phycoerythrin), chlorophyll a and carotenoids. The phycobilins are present on the outer surface of thylakiods. A number of small spherical granules rich in carbohydrates are distributed in the chromoplasm. These are called cyanophycean starch. The reserve food is stored in proteinaceous bodies, the cyanophycean granules.

Central body

The central body is nuclear in nature. It is nucleus without nucleoli and a definite membrane. The nuclear material is often dispersed in the form of a network.

Pseudovacuoles

Pseudovacuoles or gas vacuolesare found in Anabaena cells. These are gas-filled cavities that provide buoyancy and help the alga to arise to the surface of the water. They also reduce the intensity of light reaching thylakoids.

Heterocyts

A heterocyst(Gr.heteros=different + kystis=cell) is a specialize cell that differs from vegetative cell in structure of its wall and transparent contents. It arises by transformation of a vegetative cell. The cell enlarges synthesizes a three-layered peripheral wall in addition to original wall, the granular cellular contents decrease and thylakoids reorganize into concentric or reticulate pattern during transformation. There are called polar nodules.The heterocysts make cytoplasmic connections with adjacent cell through these pores. However, in mature heterocyts these pores get filled.

Heterocysts are sites of nitrogen fixation and transfer of combined nitrogen to vegetative cells between intervening heterocycts. Also, there is evidence that they are concerned with transformation of vegetative cells adjacent to them into akinetes. In some species, the heterocysts act as reproductive structures.

Akinetes

Akinetes(Gr. Akinesia=absence of motility) are non-motile spores formed by transformation of a vegetative cell. A vegetative cell enlarges, accumulates cyanophycean granules and the original cell wall becomes thickened. The thylakoids retain the original arrangement. The akinetes are resistance to environmental adversities and germinate to give rise to new filaments on return of conditions favourable for growth. The akinetes are formed next to heterocycts.

Reproduction

The most common methods of reproduction are vegetative reproduction and reproduction by formation of spores. The sexual reproduction by fusion of gametes is absent. ①

Vegetative Reproduction ②

The vegetative multiplication of filament takes place by a type of fragmentation called hormogonium formation (Gr. hormos = chain = +gonos = reproductive structure). In this process the chain of cells break into multicellular fragments.It is due to death of one or morecells in the trichome. In some cases the trichome fragments at heterocysts. The hormogonia are usually motile and capable of forming new tricomes.

Reproduction by Spore Formation

Asexual reproduction by spore is by akinete formation and endospores. In some cases heterocyst also acts as reproductive structure.

(i) Akinetes

The akinete germinates into a new filament. The protoplast of the akinete undergoes transverse division and moves through ruptured spore wall to form a new filament.

(ii) Endospores

In some species, e.g., *Anabaena cicadae*, the heterocyst contents divide to form small spores, the endosperms, which give rise to new filaments upon germination.

(iii) Heterocyst as Reproductive Structure

In Anabaena haleness the heterocyst germination to produce a new filament. The contents of heterocyst divides into two celled germ lings which undergo further division to form four celled germiling. The wall of the heterocyst ruptures at the equatorial region and germilings come out and grow into a new filament.

In some cases the protoplast of the heterocyst divides to form a number of small endospores. These spores are released by rupture in the wall, secrete a thick wall and undergo a period of rest. Each endospore germinates into a new filament by cell division.

Economic Important

The economic aspects of *Anabaena* includes:

i. **Nitrogen Fixation:** Anabaena actively participates in nitrogen fixation, therefore increases the fertility of the soil.

ii. **Increase in Fertility of Soil and Crop Yield:** Anabaena spp are grown in rice fields to increase the fertility of the soil and promotes yield of rice crop.

iii. **Symbiotic Association:** Anabaena forms symbiotic relationship with roots of cycads.

iv. **Reclamation of Saline Soils:** Anabaena is grown in saline soils where they form thick mats on the soil surface and help in reducing the pH of the soil and increasing water holding capacity of these soils.

v. **Water Blooms:** Anabaena forms water blooms in storage water and impart unpleasant smell as a result the water becomes unfit for human consumption due to presence of suspended organic matter in it.

vi. **Death to Animal:** Anabaena spp produce toxins causing deaths to animals like horses, cattle's, sheep, etc.

OSCILLATORIA

C.W = stable + hard
surounded by
musilagenus sheath

No plastid.

(C. color)
blue)

Pig ch., caroten, phycoerithrin
pycocynanin.

R.F.M sugar, glocans
protein and
cynopycin.

Taxonomic Position

Kingdom: Bacteria
Division: Cyanobacteria
Class: Cyanophyceae
Order: Oscillatoriales
Family: Oscillatoreaceae
Genus: *Oscillatoria*

Occurrence

✓ It occurs in wide variety of habitat. It is common in fresh water, damp place, ditches, drains etc. it is also found as patches on the mud surface. It is most common in moist places where abundant organic matter is present. Patches of entangled masses of filaments are often found floating on the surface of fresh water channels.

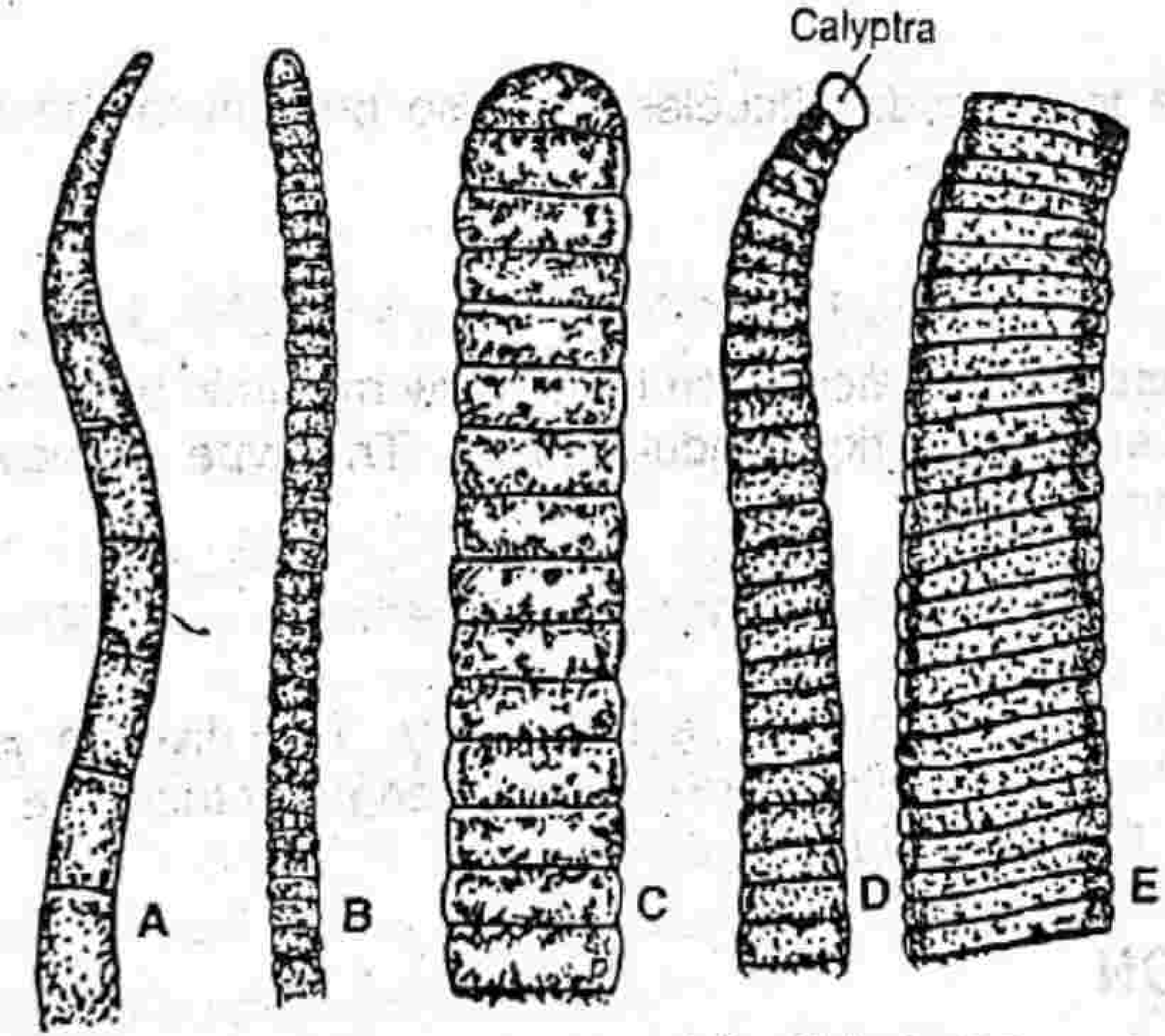


Fig. 3.3: Morphology of *Oscillatoria* spp.

Thallus

The thallus consists of free living trichome. It has distinct filamentus texture. The trichome consists of a single row of cells. The filament is unbranched and gelatinous sheet is very thin. The cells are cylindrical but broader than long. All the cells are similar in shape except the apical one, which is convex at the top. The septa are faintly visible and marked by row of granules.

Cell Structure

All the cells in trichome are similar in structure. The cells are without any mitochondria, endoplasmic reticulum and Golgi bodies.

Cell wall

Each cell has a well developed cell wall. The cell wall is being stable and hardly any mucilaginous sheath external to it.

Pigments

Plastids are absent. The pigments are found in the flattened sac like structure called lamellae. The lamellae are not organized into grana. Cells are blue in color due to the presence of phycocyanine (a blue pigment), chlorophyll, carotene and phycoerythrin.

Nucleoplasm

A definite nucleus is absent and nuclear material is present as central body, which lacks nucleolus.

Reserve food material

Reserve food is in the form of sugars and glycogens and proteinaceous material cyanophycin.

Vacuole

Some time the pseudo vacuoles are also present in the protoplast of certain species.

Movement

The characteristic of Oscillatoria is the slow rhythmic but active movement of the trichome. The movement is jerky pendulum like. This type of movement is termed as oscillatory movement.

Growth

The growth of the trichome is intercalary. The division is right angle to the longitudinal axis. This result in the increase in the length of trichome, which is never more than one cell wide. The cell divides by amitotically.

REPRODUCTION

Fragmentation

The filament breaks into two or more fragments. Each fragment grows to produce new plant body.

Oscillatoria reproduce vegetatively. The only method of reproduction is the formation of hormogones. The break takes place where a dead cell is situated.

Necridia

(dead cells) = found in ocelolitoria.

During the growing season the cell in the trichome collapses. The protoplast is change into mucilage. The mucilage filled cells are called necridia. The dead cell loses its turgidity. The mutual pressure on the wall of adjacent cell released. They become convex so that the dead cell appears biconcave. The cells are separated in the form of hormogones from the dead cells.

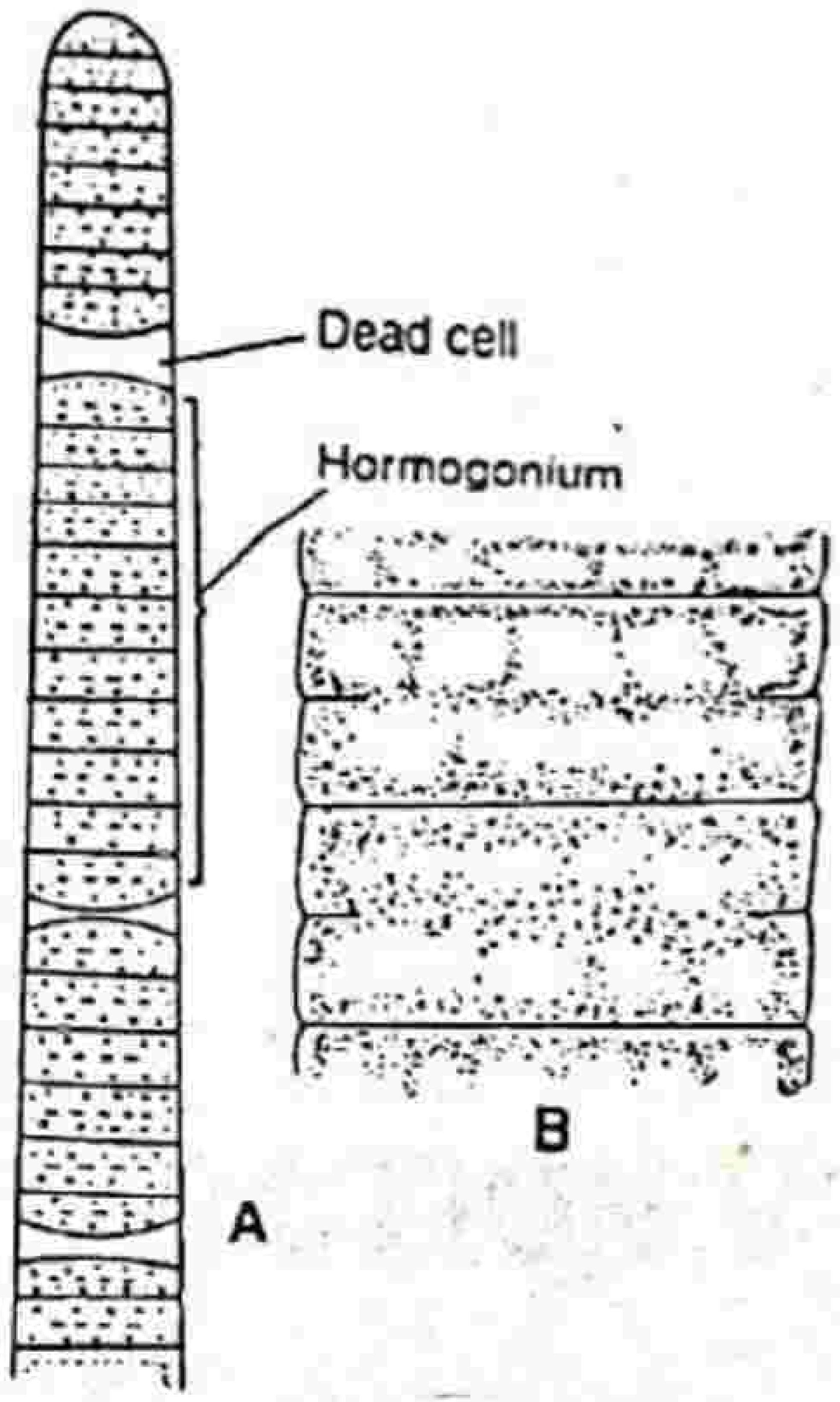


Fig. 3.4: (A) Formation of hormogones by dead cell (B) Cell Structure.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are cyanobacteria?
2. Why cyanobacteria are called as blue green algae?
3. Enlist pigments of cyanobacteria?
4. What are role of blue green algae in nitrogen fixation?
5. What is heterocyst? Give its importance.
6. What are affinities cyanobacteria with red algae?
7. Give taxonomic position of Nostoc.
8. What are pseudovacuoles?
9. Give economic importance of cyanobacteria.
10. What are akinetes?

B. Long Questions

1. Describe Asexual reproduction in cyanobacteria.
2. What are the economic importance of cyanobacteria.
3. Describe general characteristics of bacteria.
4. Describe structure and reproduction in Nostoc.
5. Describe structure and reproduction in Oscillatoria.
6. Give difference between Nostoc and Anabaena.

SECTION V

THE ALGAE

Chapter 4

THE ALGAE (V.vimp)

General Characters

Alge are the chlorophyllus thallophytes that can manufacture their own food and they produce O_2 *during photosynthesis. So they are called as autotrophic thallophytes.*

The term thallus is used for a plant body that is not differentiated into root, stem and leaves and lacks vascular system. The study of algae is known as phycology (phycos=seaweed). Algae have simple, unicellular non-jacketed sex organs and have no embryo development.

Naked sex-organs

Habit and Habitat

The algae are predominantly aquatic and are found both in fresh and salt-water habitats. According to the habitat the algae can be classified as

a. Aquatic Algae

Majority of algal genera are aquatic. They are found in ponds, lakes, ditches, streams, running water and oceans. e.g. *Volvox, Chara* etc.

b. Terrestrial Algae

A few species are terrestrial found growing on moist shady soils or rocks. e.g. *Vaucheria*, few species of *Nostoc*.

Air → Plants

c. Aerophytes S.Q

Such algae adopted for aerial mode of life and occur in tree trunks, moist wall etc.

d. Cryophytes

They are found on mountain peaks covered with snow. They impart color to mountains. e.g. Chlamydomonas.

e. Thermophytes

Hot These algae occur in hot springs. They can tolerate upto 85°C. e.g. *Haplosiphon*.

(Algae+fungi) → relationship

f. Algae of Unuseual Habitat

Some species grow on or inside other plants (up) (epiphytes and (inside) endophytes). Other species form a symbiotic relationship with fungi (lichens) or bryophyte thalli (Anthoceros). Some algae live in or out side the animal body (Zoochlorella)

Organization of Thallus

no root/stem/leaves

The algae exhibit a wide variety of thallus organization. The range of thallus organization is from unicells, colonial, filamentous and heterotrichous plant body. In marine algae, the thalli exhibit high degree of differentiation. The parts of the plant body bear superficial resemblance to the roots, stem, and leaves of higher plants. The length of main axis in some species attains a height of many meters.

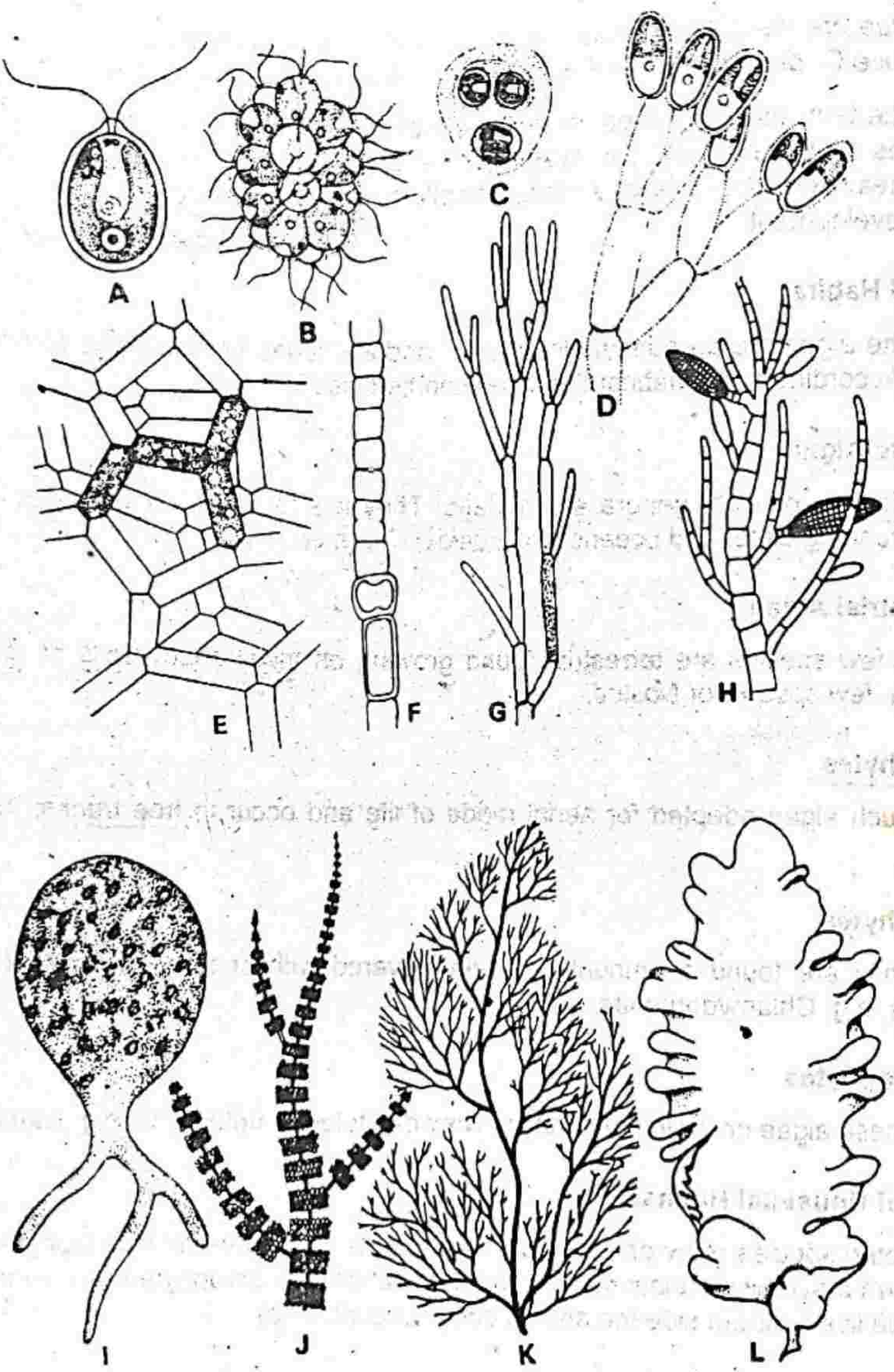


Fig. 4.1: Algal thalli.

Structure of Algal Cell

The algal thalli are formed of two types of cells:

i.Prokaryotic Cells

The cells in which, the nucleus is not surrounded by nuclear membrane. The DNA is in the form of a nuclear body. The photosynthetic pigments are organized in membranous sacs, the thylakoids. The mitochondria, Golgi complex, and endoplasmic reticulum are absent. The cell wall is formed of a lipoproteinaceous complex. These cells are characteristics of Cyanophyta (blue-green algae).

ii.Eukaryotic Cells

The cells that contain a well organized nucleus. The cytoplasm is bounded by plasma membrane. The nucleus is spherical or ellipsoidal and contains nucleolus and chromosomes bounded by nuclear membrane. The cytoplasm contains endoplasmic reticulum. Similarly Golgi bodies and membrane bound energy sites, the mitochondria are also present.

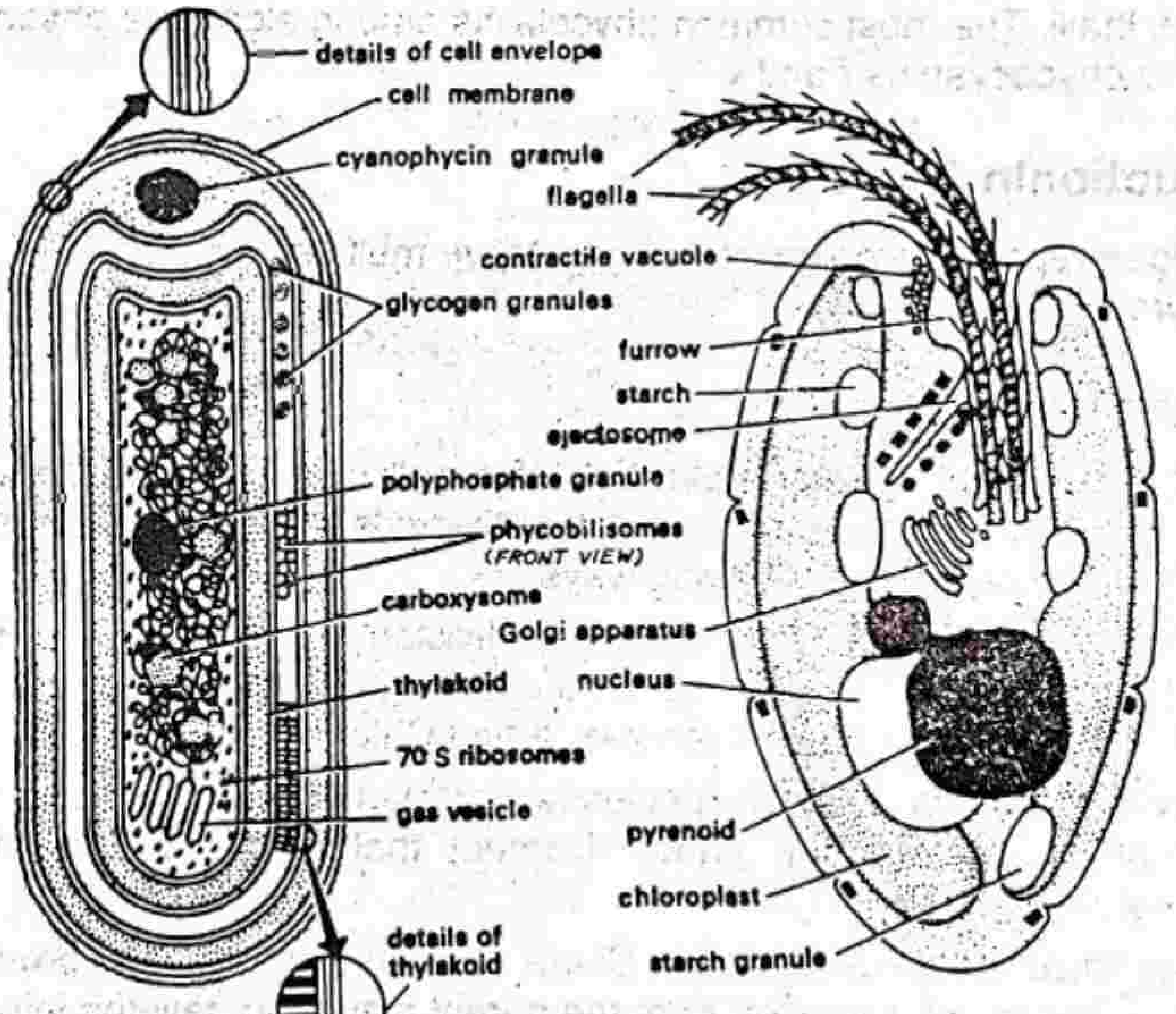


Fig. 4.2: Diagrammatic representation of algal cells.

Algal Pigments S.Q

The colour of algal thallus vary in different divisions because of presence of characteristics chemical compounds called pigments. The main algal pigments are chlorophylls, carotenoids and phycobilins. These are used to classify algae since a particular colour dominates in each division.

i. Chlorophylls

Five different kinds of chlorophylls, a, b, c, d and e, are found in algae. These provide green colour to the thalli, for example in division Chlorophyta and Charophyta.

ii. Carotenoids

The carotenoids are a group of about 60 different kinds of yellow, brown, orange and red pigments. These are divided into two main groups:

a. **Carotenes:** These are long chain, fat-soluble, unsaturated hydrocarbons ($C_{40}H_{56}$). Five different kinds of carotenes have been recognized so far. These are alpha-, beta-, -e, -Y and lycopene. These provide characteristics colour to members of *Bacillariophyta and Rhodophyta*.

b. **Xanthophylls:** These are yellow to brown coloured oxygen containing long chain fat-soluble hydrocarbons ($C_{40}H_{56}O$). The most commonly met xanthophylls among algae are lutein, fucoxanthin (brown algae), and myxoxanthin (blue-green algae).

c. **Phycobilins:** These are tetrapyrrolic compounds joined to globulin proteins. They are water-soluble and provide red (red algae or blue colour (blue-green algae) to the thalli. The most common phycobilins among algae are phycoerythrins r and c, and phycocyanins r and y.

Reproduction In Algae

Algae reproduce by means of vegetative multiplication, asexual reproduction and sexual reproduction.

(1) Vegetative Multiplications

The process involves separation of a cell or a group of cells from the parent individual which directly develop into new individuals that resemble their parents. It may take place by any one of the following ways:

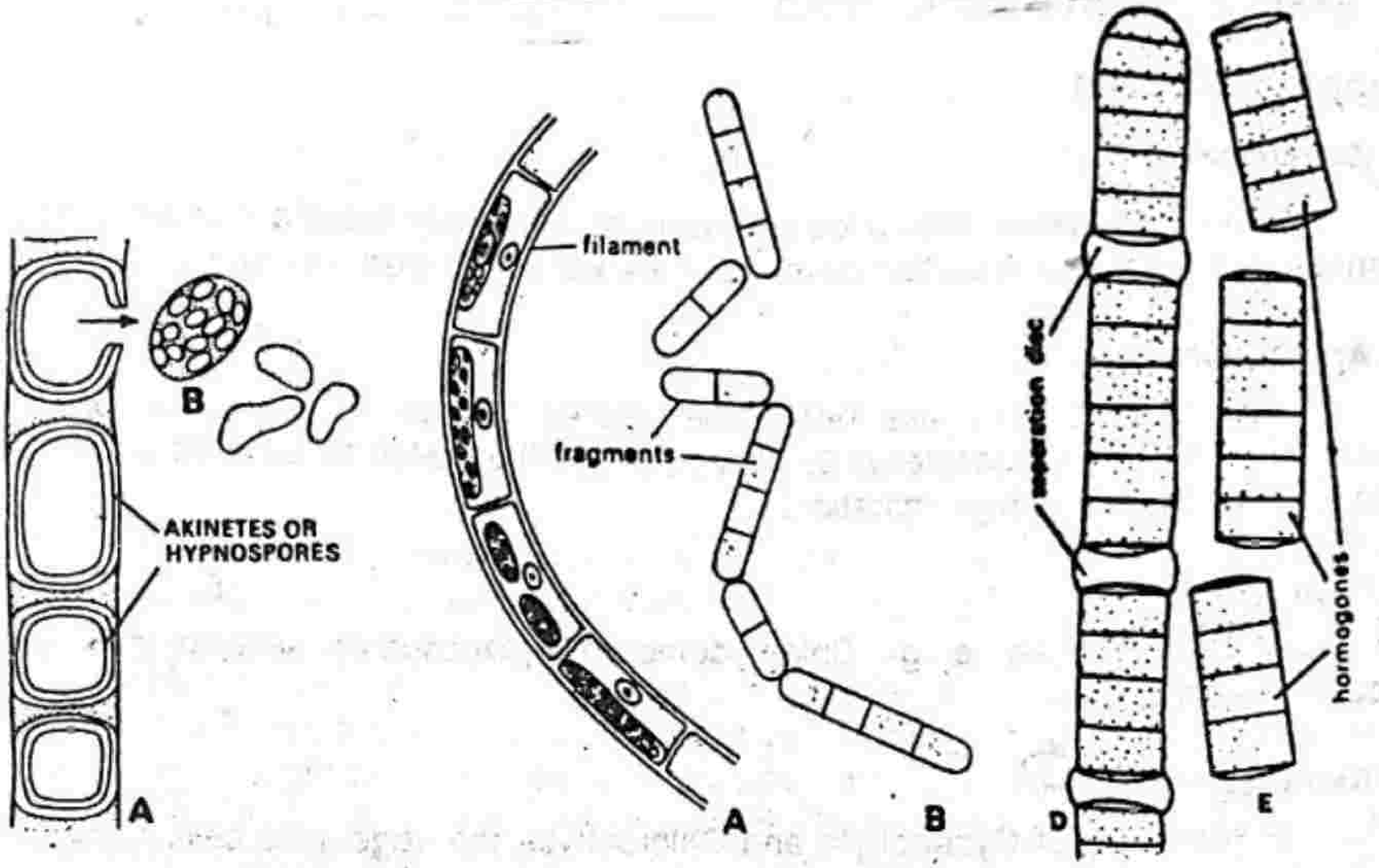
i. **Fission:** It involves simple mitotic division resulting in the formation of two daughter cells. The cell separated and grow to the size of parent cell. e.g. Unicellular members of Cyanophyta and Chlorophyta.

ii. **Fragmentation:** In some species few or many-celled segments called fragments, break away from the parent filament that grow into new filaments by cell division. e.g. in Spirogyra.

iii. [illegible] **Adventitious Branches:** In *Chara* certain nodal cells produce adventitious branches which break off from the parent plant and develop into new plants.

iv. **Tubers:** Tubers are outgrowth that store reserve food in them and can overcome unfavourable growing periods. In *Chara* rhizoids or the nodes buried in the soil develop into tubers. They detached from the parent and develop into new plants.

v. **Budding:** Buds is an outgrowth that develops from a cell. It develops into a new plant after separation from parent plant. ✓



Akinetes **Fragmentation** **Harmogones & Separation Discs**

Fig. 4.3: Vegetative reproductive bodies.

(2) Asexual Reproduction

Asexual reproduction does not involve sexes. It is brought by formation of specialized reproductive units called spores.

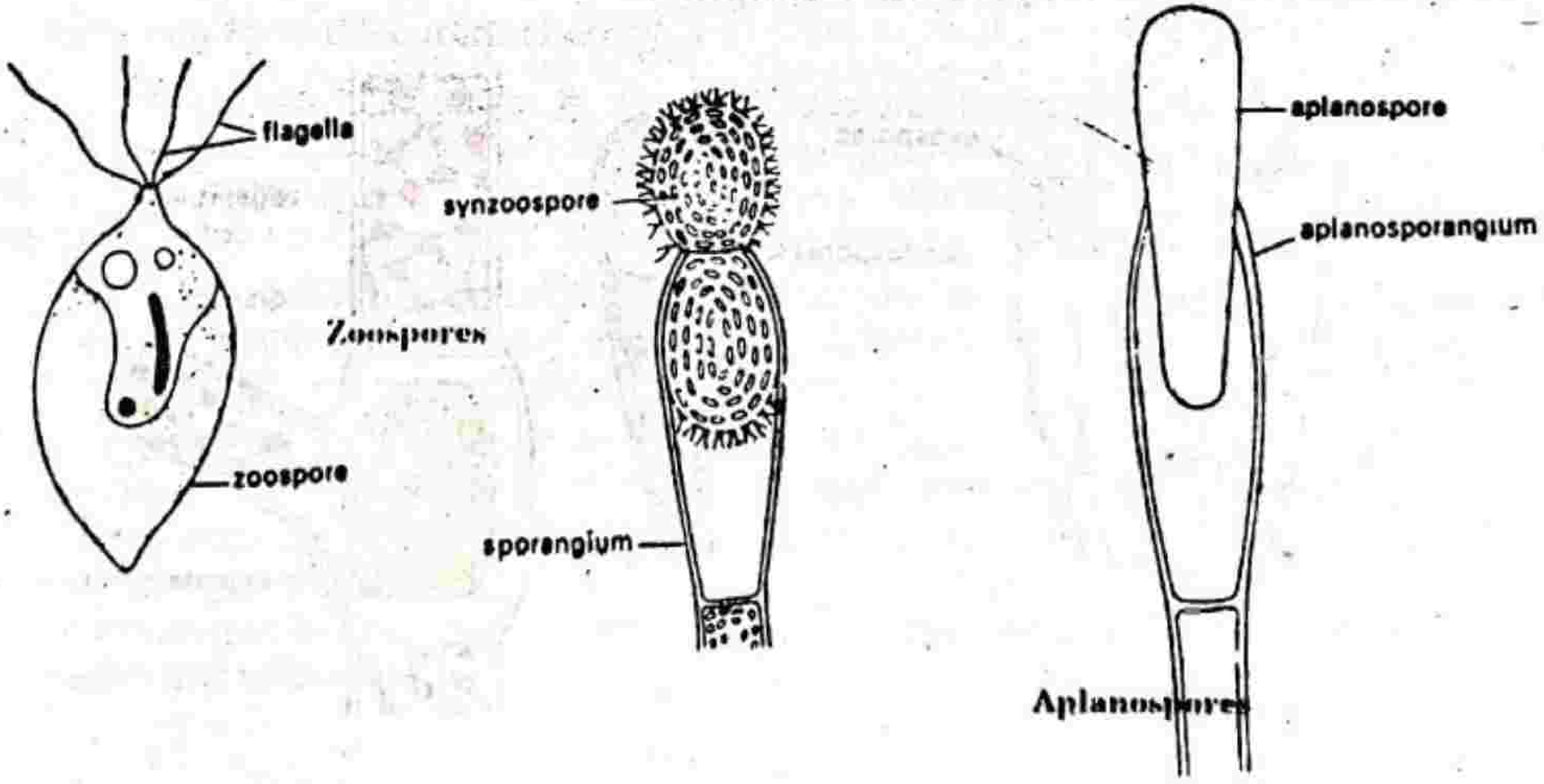


Fig. 4.4: Zoospores and aplanospores.

flagella (✓) (X)

Types of Spores

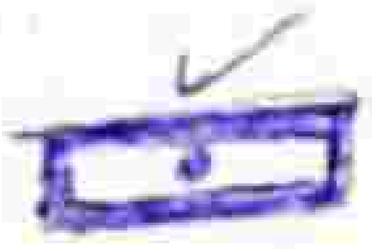
1. Zoospores

The motile spores are called as zoospore. Generally these are ovoid or spherical in shape (fusiform), but in certain cases they are kidney-shaped (reniform).

2. Aplanospores

The aplanospores are non-motile spores formed by terrestrial species.e.g *Vaucheria*. These are considered to be zoospores that failed to develop flagella. They produce new plants upon germination.

3. Hypnospores ⇒



In certain algae, e. g., Chlamydomonas aplanospores secrete thick walls to become hypnospores.

4. Akinetes ⇒

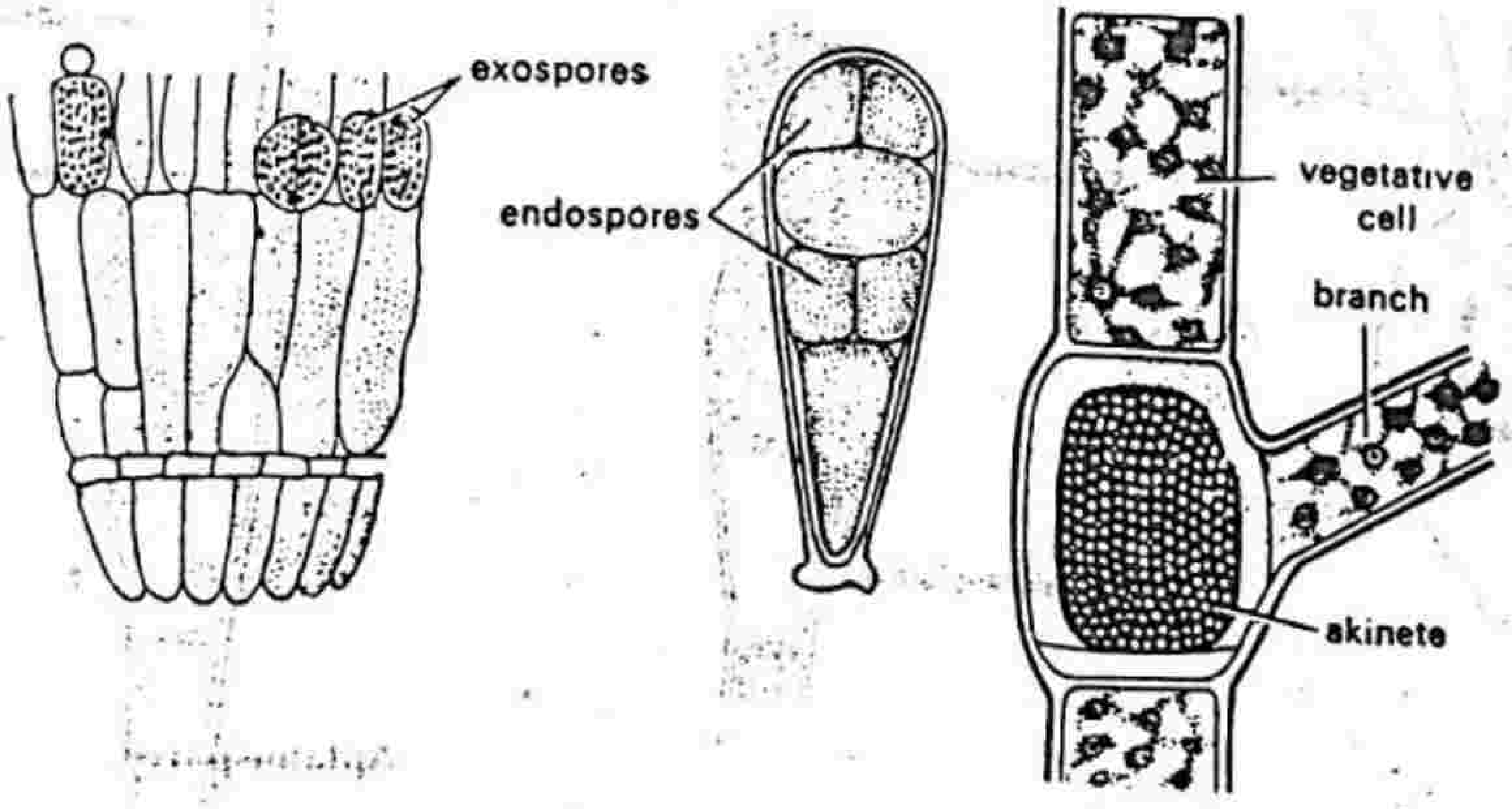
In members of Cyanophyta and Chlorophyta, the vegetative cells round off and the original parent wall becomes extremely thick to form akinetes.

5. Endospores

In some cases the protoplast divides to form spherical units which secrete new walls. These are called endospores.

6. Exospores

In some species the cell wall ruptures at distal end and spores are cut off from the exposed protoplast. They are called exospores.



Exospores **Enodspores** **Akinetes**

(fig.)Fig. 4.5: Perennating organs in algae.

7. Tetraspores

In members of Phaeophyta four non-motile spores are produced per sporangium. These are called tetraspores.

8. Monospores

In *Batrachospermum* a single non motile spore called monospore is formed in each sporangium.

Sexual Reproduction

1n+1n = 2n

Sexual reproduction involves fusion of two haploid cells called gametes which fuse to form diploid zygote. The process of fusion is called fertilization. The gametes may be morphologically identical, i. e., similar in size and structure, called isogametes; or differ in size and shape and known as heterogametes. The smaller or active gametes are termed male gametes, whereas the larger or passive ones are called female gametes. The gametes may be produced on the same thallus (monoecious or homothallic) or produce on different thalli (dioecious or heterothallic). The gametes may be produced in ordinary vegetative cells or specialized organs, the gametangia.

Generally the sexual reproduction may be isogamous or heterogamous type.

Isogamous Sexual Reproduction

S.Q

If two gametes, similar and size and structure (isogametes), fuse to form the zygote, it is called isogamy and the sexual reproduction is known as isogamous sexual reproduction. It is simplest and most primitive type of sexual reproduction found among simpler forms of algae.

Heterogamous Sexual Reproduction

S.Q

If two gametes, dissimilar in size and structure (heterogametes) fuse to form zygote, it is called heterogamy and the sexual reproduction is known as heterogamous sexual reproduction. It is advanced type of sexual reproduction. The heterogamous sexual reproduction is of two types, anisogamy and oogamy.

i. **Anisogamy:** It involves fusion of a larger passive gamete (female) and a smaller active gamete (male), for example in Chlamydomonas. The gametes are produced in ordinary vegetative cells usually.

ii. **Oogamy:** It is highly advanced type of sexual reproduction which is characteristics of filamentous forms of algae. The gametes are produced in gametangia. The male gamete producing structures are antheridia whereas the female gamete producing structures are oogonia. A single large egg or ovum is produced in each oogonium and many small, active male sperms are formed in each antheridium.

LIFE CYCLES IN ALGAE

The sequence of events through which an organism passes from zygote to zygote of the next generation is called its life cycle. Generally five types of life cycles are found among sexually reproducing algae.

i.Haplontic Life Cycle

The life cycle during which the haploid phase is long and represents almost all the stages of the life except the diploid phase which is represented by zygote is called haplontic life cycle. A sexual haploid plant with only zygote diploid is called a haplont.

The haplontic life cycle is exhibited by most members of Chlorophyta where the main plant body is haploid and reproduces by vegetative multiplication or formation of mitospores (spores formed as a result of mitosis). It reproduces sexually when the conditions become unfavourable for growth. The haploid gametes fuse to form diploid zygote which secretes a thick wall to form a resting zygospore. At the advent of favourable growing season the zygospore nucleus undergoes meiosis to form meiospores which germinate to give rise new haploid plant.

ii.Diplontic Life Cycle

The life cycle in which most part of the life cycle is occupied by diploid phase and the haploid phase is represented by gametes only is called diplontic life cycle. A sexual plant in which the haploid stage is represented by haploid gametes is called a diplont.

This type of life cycle is exhibited by some members of Chlorophyta, all members of Bacillariophyta and some members of Phaeophyta. The vegetative plant body is a diploid sporophyte which bears sex organs in which haploid gametes are produced. The meiosis takes place before spore formation. The gametes unite to establish diploidy. The zygote divides mitotically to form a diploid sporophyte. In some species both phases are morphologically similar (isomorphic), for example in *Ulva* and *Ectocarpus*, whereas in others the alternating generations are dissimilar (heteromorphic), for example in Fucus.

iii.Diplohaplontic Life Cycle

The life cycle in which there is a haploid and a diploid phase which alternate regularly with each other is called diplohaplontic life cycle. The plant having two cytologically different kinds of individuals that exhibit alternation of generations during its life cycle is called a diplobiont.

In this type of life cycle the plants possess two distinct vegetative thalli with different chromosome numbers. One of these is haploid, reproduces sexually and known as gametophyte. The other is diploid, reproduces asexually and called sporophyte. Both generations alternate with each other regularly.

v.Haplodiplobiontic Life Cycle

The life cycle that is characterized by presence of two diploid phases and one haploid phase is called haplodiplobiontic life cycle. This life cycle is also called triphasic life cycle.

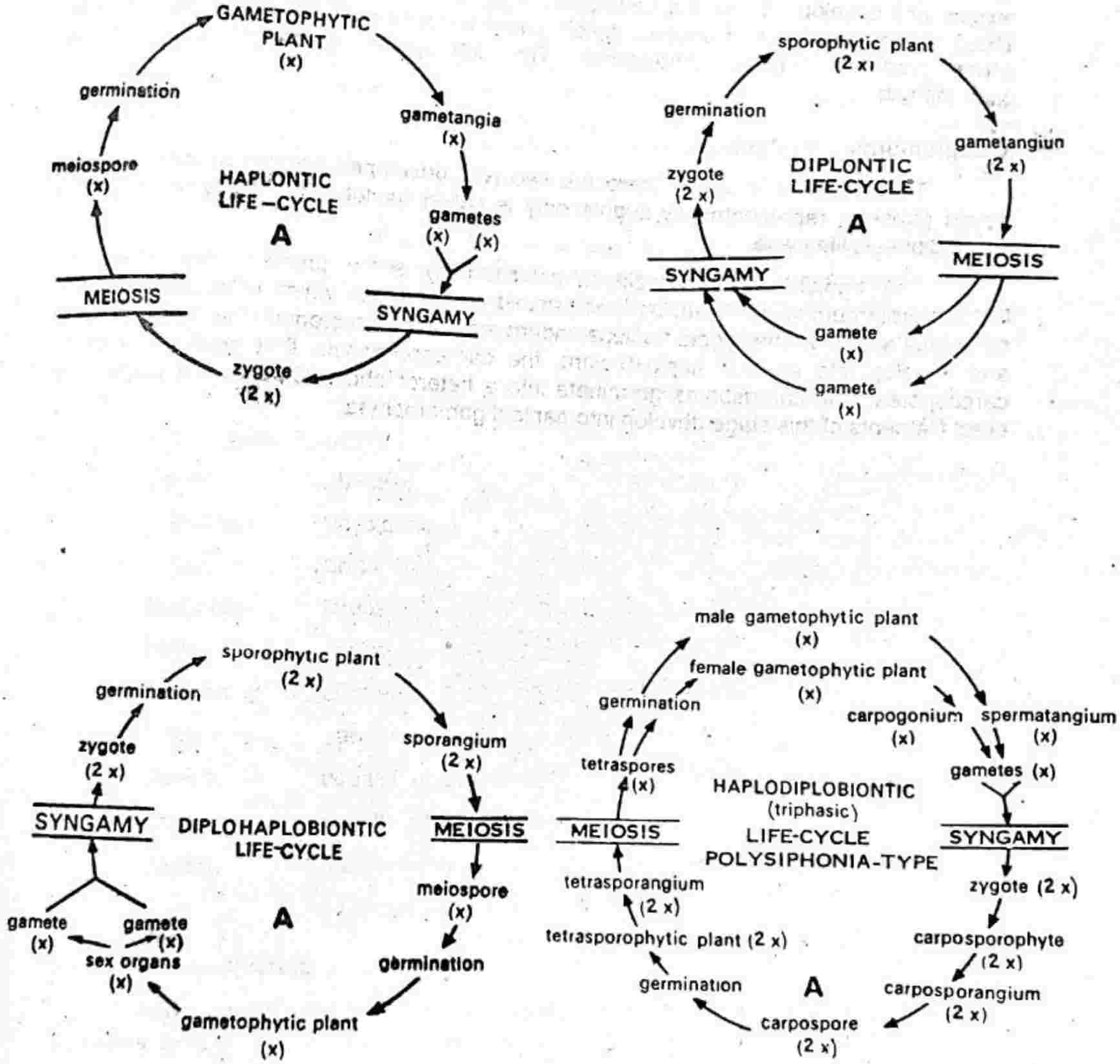


Fig. 4.4: Life cycles in algae.

This type of life cycle can be explained with the life history of Polysiphonia. It is heterothallic gametophyte. The fusion of gametes result in zygote which divides by mitosis and develop into diploid carposporophyte which produces diploid carpospores. These spores develop into another diploid spore producing phase, the tetrasporophyte which produces haploid tetraspores. The tetraspores germinate into haploid gametophyte.

iv.Haplobiontic Life Cycle

The life cycle in which there are two well developed haploid phases and the diploid phase is represented by zygote only is called haplobiontic life cycle. It is also called diphasic life cycle.

The haplobiontic life cycle is exhibited by some primitive red algae like Batrachospermum where plant body is haploid gametophyte which produces gametes, spermatia and ova. The zygote nucleus undergoes meiosis to produce four haploid nuclei and develop into another haploid plant, the carposporophyte that produces haploid carpospores. The carpospores germinate into a heterotrichous Chantransia stage. The erect filaments of this stage develop into haploid gametophyte.

CLASSIFICATION

The classification is scientific organization of the organisms in a heirarchical series of groups on the basis of common characters. The smallest group into which the algal plants are arranged is the species, a group of individuals that resemble each other closely, however smaller groups within species called varieties and forms are also recognized. Closely related species are grouped into a genus. The genera with common characters are grouped into a family, and families are aggregated into orders. The orders are grouped into classes which in turn form a division. All the divisions make a kingdom.

Nomenclature

The Greek word for algae is phykos and according to International Rules of Botanical Nomenclature, word phykos must be incorporated into the name assigned to an algal group, because it will indicate an idea about its relation with algae. The International Code of Botanical Nomenclature has recommended the following suffixes for different categories of algae.

Division	phyta
Sub-division	phytina
Class	phyceae
Sub-class	phycideae
Order	ales
Sub-order	inales
Family	aceae
Sub-family	oideae
Tribe	eae
Genus	usually a Latin name
Species	usually a Latin name
Variety	a Latin word
Form	a Latin word

Basis of Classification

Algae are divided into several classes on the basis of cell structure, nature of pigments, type of reserve food and methods of reproduction.

The other characters used in the classification of algae include: shape of chromatophores, presence or absence of organized nucleus, cell wall, methods of reproduction and ecological aspects such as habit, habitat, etc.

The modern algologists classify these plants of algal organisation into 11 divisions, namely, Cyanophyta, Chlorophyta, Charophyta, Xanthophyta, Chrysophyta, Bacillariophyta, Pyrrophyta, Cryptophyta, Euglenophyta, Phaeophyta and Rhodophyta. The relevant portion of this classification with slight modifications is given below.

Division	1.	**CYANOPHYTA** (Blue-green algae) including a single class.
Class	1.	**Cyanophyceae** comprising 7 orders
Order	1.	**Chorococcales**
Family	1.	Chroocoeccaceae: Type *Chroococcus*
Order	2.	**Chamaesiphonales** comprising 3 families
Order	3.	**Oscillatoriales** with 1 family
Family	1.	Oscillatoriaceae: Type *Oscillatoria*
Order	4.	**Nostocales** wit ha single family
Family	1.	Nostocaceae: Type *Nostoe* or *Anabaena*
Order	5.	**Scytonematales** including 1 family
Family	1.	Scytonemataceae: Type *Scytonema*
Order	6.	**Stigonematales** with a single family
Family	1.	Stigonemataceae: Type *Stigonema*
Order	7.	**Rivulariales** comprising one family
Family	1.	Rivulariaceae: Type *Rivularia*
Division	2.	**CHLOROPHYTA** with class
Class	1.	Chlorophyceae comprising 9 orders
Order	1.	**Volvocales** with 3 families
Family	1.	Chlamydomonadaceae: Type *Chlamydomonas*
"	2.	Volvocaceae: Type *Volvox*
"	3.	Tetrasporaceae: Type *Tetraspora*
Order	2.	**Chlorococcales**
Family	1.	Chlorellaceae: Type *Chlorella*
Family	2.	Hydrodictyaceae: Types *Hydordictyon* and *Pediastrum*
Family	3.	Protosiphonaceae: Type *Protosiphon*
Order	3.	**Ulotrichales**
Family	1.	Ulotrichaceae: Type *Ulothrix*
Family	2.	Microsporaceae: Type *Microspora*
Family	3.	Cylindrocapsaceae: Type *Cylindrocapsa*
Order	4.	Ulvales
Family	1.	Ulvaceae: Type *Ulva* and *Enteromorpha*
Order	5.	**Oedogoniales**
Family	2.	Oedogoniaccae: Type *Oedogonium*
Order	6.	**Cladophorales**

Family	1.	Cladophoraceae: Type *Cladophora* and *Pithophora*
Order	7.	**Chaetophorales**
Family	1.	Chaetophoraceae: Types *Stigeoclonium Drapamaldia* and *Draparanaldiopsis*
Family	2.	Trentephliaceae: Type *Trentepohlia*
Family	3.	Coleochaetaceae: Type *Coleochaete*
Family	4.	Pleurococcaceae: Type *Pleurococcus*
Order	8.	**Zygnemales**
Family	1.	Zygnemaceae: Type *Zygnema* and *Spirogyra*
Family	2.	Desmediaceae: Type *Closterium* and *Cosmarium*
Order	9.	**Siphonales** or **Caulerpales**
Family	1.	Caulerpaceae: Type Caulerpa
Division	3.	**CHAROPHYTA** (Stoneworts) with one class
Class	1.	Charophyceae comprising one order
Order	1.	**Charles** with a single family;
Family	1.	Characeae: Type *Chara* and *Nitella*
Division	4.	**EUGLENOPHYTA** with one order
Order	1.	**Euglenales:** Type *Euglena*
Division	5.	**PYRROPHYTA**
Division	6.	**XANTHOPHYTA** with a single class
Class	1.	**Xanthophyceae** (Yellow-green algae)
Order	1.	**Heterosiphonales**
Family	1.	Botrydiaceae: Type *Botrydium*
Family	2.	Vaucheriaceae: Type *Vaucheria*
Division	7.	**BACILLARIOPHYTA** with one class
Class	1.	Bacillariophyceae; Type *diatoms*
Division	8.	**CHRYSOPHYTA**
“	9.	**CRYPTOPHYTA**
“	10.	**PHAEOPHYTA** with three classes:
Class	1.	**Isogeneratae**
Order	1.	**Ectocarpales**
Family	1.	Ectocarpaceae: Type *Ecotocarpus*
Order	2.	**Dictyotales**
Family	1.	Dictyotaceae: Type *Dictyota*

Class	2.	**Heterogeneratae**
Order	1.	Laminariales
Family	1.	Laminariaceae: Type *Laminaria*
Class	3.	**Cyclosporae**
Order	1.	**Fucales**
Family	1.	Fucaceae: Type *Fucus*
Family	2.	Srgassaceae: Type *Sargassum*
Division	11.	**RHODOPHYTA** with one class
Class	1.	**Rhodophyceae**
Sub-class	1.	**Bangioideae**
Sub-class	2.	Florideae
Order	1.	**Nemalionales**
Family	1.	Batrachospermaceae: Type *Batrachospermum*
Order	2.	**Ceramiales**
Family	1.	Rhodomelaceae: Type *Polysiphonia*

Silent features of important classes of Algae

Class 1 **Chlorophyceae** (Green Algae). The colour of members of the class is green or grassgreen due to presence of chlorophyll *a* and *b*, xanthophylls and carotenoid, the cells have organised nucleus (eukaryotic), reserve food material is starch rarely oil e.g., in *Vaucheria*, pyrenoids usually present in chloroplast except in the members of order siphonales; motile cells have variable number of flagella or cilia which are equal in size, sexual reproduction ranges from misogamy to oogamy; mostly fresh water but few forms are marine.

Class 2 **Xanthopyceae** The members are yellow green in colour due to excess of xanthophylls; majority of the members are fresh water, few are marine; pyrenoids absent in the chromatophores and oil is reserve food material; sexual reproduction is of rare occurrence but if present is isogamous and motile sex cells have flagella-two in number and unequal in length.

Class 3 **Chrysophyceae** The members of the class are marine and fresh water both, usually found in cold water bodies; brown or orange in colour owing to the excess of an accessory pigment Phycochrysin; reserve food material is oil and leucosin which is protein like substance; sexual reproduction rare and if present is isogamous, the motile cells have one, tow or rarely three flagella of equal or rarely of unequal size.

Class 4 **Bacillariophyceae**. Commonly known as **diatoms** the members are fresh water and marine both; members have diatomin as principal pigment and are yellow or golden brown in colour; cell wall partly solidified and partly pectose and is divided into two symmetrical halves; variously ornamented which is of taxonomic importance; Pyrenoids present in chromatophores and reserve food material is oil, volutin and lacunas; sexual reproduction is of unique type and the members are diploid unicellular organisms but sometimes may form colonies.

Class 5 **Cryptophyceae.**The members are fresh water and marine and are of diverse colour i.e. brown, red, olive green or sometimes bluish green; the cells have two large parietal chloroplasts with pyrenoids and starch is reserve food material; Mostly the forms are flagellates and have two flagella which are unequal in length. Cysts are common and endogenous and sexual reproduction is isogamous in one species only.

Class 6 **Dinlphyceae.**Most of the members are unicellular and motile, biflagellate and have sculptured cell wall The nucleus is prominent and large and chromatophores are discoid, dark yellow or brown in colour due to presence of red phycopyrrin, dark red peridinin and yellow green chlorophyllin which are collectively termed Pyrophyll; reserve food material is starch and fat; sexual reproduction rare and is isogamous when present.

Class 7 **Chloromonadineae.**Members included in the class are bright green in colour owing to the excess of xanthophyll and cells have numberous discoid chromatophores; Reserve food material is fat and individuals reproduce by longitudinal divisions.

Class 8 **Euglenineae** (Euglenophyceae) unicellular and motile forms, with one or tow flagella and are found in fresh water bodies or in saline habitats; animal like naked flagellates. Mostly the members are green free swimming and solitary but some forms may form gelatinous colonies whereas few of them may also get attached; halophytic form have several green chloroplasts while other forms lack it. Reproduction usually takes place by fission.

Class 9 **Phaeophyceae** (Brown Algae). The members are mostly marine, brown in colour and have complicated and organised thalli; commonly known as 'sea weeds', of great economic importance; the cells have several chromatophores with excess of fucoxanthin alongwity other pigments; Reserve food material is alcohol and polysaccharides; reproduction is vegetative and sexual both and the motile sex cells are biflagellate having two flagella laterally inserted and of unequal length; sexual reproduction ranges from isogamy to oogamy.

Class 10 **Rhodophyceae** (Red Algae). Majority of the forms are marine and only few are fresh water forms, usually red or dark red in colour due to presence of accessory pigments c-phycocyanin and r-phycoerythrin; Reserve food material is 'floridean starch', thallus is organised and exhibits complex differentiation; Plasmodesmata is present between the cells except in the members of Protoflorideae, sexual reproduction is specialised and oogamous; motile cells altogether absence in the class and even the male sex cells are non motile structures.

Class 11 **Myxophyceae** (Blue green Algae). Mostly fresh water forms with simple thallus organisation, look bluish green in colour owing to the presence of accessory pigments phycocyanin and phycoerythrin; cy-phycocyanin is the overmasking blue pigment while the red pigment phycoerythrin is also found in peripheral regions in dispersed condition; pigments are not localized in organised and definite chromatophores and cells lack well defined nucleus (prokaryotes), Photosynthetic products are polysaccharide and glycogen; sexual reproduction is completely absent and motile cells are not produced at any stage of life cycle.

ECONOMIC IMPORTANCE OF ALGAE

The use of algae is very old and is mentioned in the Chinese poetic literature about 600 B.C. The phycologists are continuously working to get hold of their economic importance and have unearthed many beneficial as well as harmful economic aspects of algae.

Beneficial Aspects of Algae

Some of the beneficial roles exhibited the algae are as followings:

i.Role as Primary Producers

Because of their photosynthetic abilities the algae are the primary producers of the aquatic environments. They provide food and energy to the animal life, produce oxygen and take up carbon dioxide produced during respiration which is injurious for living organisms especially fishes.

ii.Source of Food

More than 100 species belonging to green-, brown- and red-algae are used as food for humans because of presence of proteins, carbohydrates, minerals and vitamins, either in the cell wall or in the cytoplasm. These include *Monostroma, Ulva, Codium* and Chlorella. The highest food value is estimated in brown algae.

The algae also afford as food for animals especially in coastal countries. *Laminaria, Sargassum, Fucus and Ascophyllum* are used as fodder for animals. *Fucus* is used in henfeed as its usage result in eggs with high iodine contents. Similarly the algae serve as primary food for fish. Certain fishes such as Tilapia feed on algae exclusively.

iii.Industrial Use

Many algae yield certain chemical products which are used in various industries for various purposes. Some of these products and their uses are:

a. **Agar-Agar:**It is dried, jelly-like, non-nitrogenous extract obtained from some genera of Rhodophyta like *Gelidium, Gracilaria, Ahnfeltia, Hypnea, Gigartina, Phyllophora*, etc. It is used as base for different culture media in laboratory for culturing microorganisms because of its food value and ability to afford good range of temperature for culturing.

b. **Alginates:**These are alginic acid and their derivatives, the most common being algin. They are usually extracted from the middle lamella and primary walls of the brown- and red-algae. The alginates are used in rubber-tyre industry, paints, ice-creams and in preparation of flame-proof fabrics and plastic articles.

c. **Carrageenin:**It is a carbohydrate mucilage extracted from red algae used as clearing agent in beer preparation, in preparation of tooth-pastes, cosmetics, paints and in pharmaceutical industries.

d. **Iodine:**The members of brown algae such as *Laminaria and Fucus* yield iodine.

e. **Diatomite:**It is cell wall material of diatoms. The deposits of fossil frustules of diatoms are known as diatomaceous earth. It is used variously such as food for many aquatic animals, for filtration processes in sugar refining and brewing industry, for production of heat-proof bricks, in manufacture of car-polishing creams, manufacture of water-glass, and preparations of bleaching powders. Due to presence of about 11% oil (by volume) in the diatom cells it is considered that the oil supply of the world is of diatom origin. Fossilized diatom shells are valuable indicators for presence of oil and bitumen at a place.

iv.Antibiotics and Medicines

Some algae yield antibiotics, e. g., *Chlorellin* is obtained from green alga Chlorella, that inhibits the growth of certain bacteria. Similarly some species of Polysiphonia produce antibacterial substances which are effective against gram-negative and gram- positive bacteria. An antibiotic is obtained from a diatom *Nitzschia palea* which is effective against Escherichia coli. Because of high iodine contents, brown algae is used in manufacture of various goiter medicines.

v.Nitrogen Fixation

The conversion of atmospheric nitrogen into nitrogenous compounds is one of the major roles being played by the algal plants especially by the members of Cyanophyta (blue-green algae). A high rice yield has obtained when the rice fields were inoculated by certain nitrogen- fixing blue-green algae.

vi.Fertilizers

Due to presence of phosphorus, potassium, calcium and some trace elements, the sea-weeds (brown algae) are used as fertilizers in most of the coastal countries of the world. For example *Chara* is used to overcome calcium deficiency in the fields, and Fucus is used as a common manure.

vii.Source of Minerals

Kelps (brown algae) are variously used for their mineral contents in preparations of soap and glass due to presence of soda contents, for extraction of potash and iodine, and as source of ammonia and charcoal. Some sea-weeds (brown algae) are rich source of iron, zinc, copper, manganese and boron. Bromine is extracted from red alga Polysiphonia.

viii.Sewage Disposal

Sewage mainly consists of domestic and industrial wastage and contains many organic and inorganic constituents in dissolved or suspended form. The effective disposal of sewage requires oxygen and this the oxygenation is brought about by the algal members present in the sewage like Chlamydomonas, Euglena, Chlorella, etc. The oxygenation by algae also helps to avoid unpleasant odour coming out of sewage bodies.

ix.Land Reclamation

During rainy season, many members of Cyanophyta and Chlorophyta develop on the rain-affected soils and help in checking the soil erosion on disturbed or burnt soils. Therefore, these algae act as binding agents. Similarly algae like *Nostoc*, and *Anabaena* grow as thick substratum on the surface of saline user soils and help in reclamation of these soils. These plants help in reducing the pH of the alkaline soils and increasing the water-holding capacity of these soils making these useful once again.

Harmful Aspects of Algae

Some of the harmful aspects of algae are:

i.Contamination of Water Reservoirs

The algae shows a luxurious growth in water reservoirs meant for domestic supplies. Such algae include members of Cyanophyta like *Nostoc*, *Anabaena*, *Microcystis* and *Oscillatoria*; members of Chlorophyta such as *Chlamydomonas* and *Volvox*; and some diatoms. Their abundant growth interferes the filtration process and also brings bad taste to water due to decay of dead algal plants.

ii.Water Blooms

Sometimes algal plants show profuse growth and form quite apparent bodies called water blooms. Usually the members of Cyanophyta form water blooms in fresh-waters and members of Dinoflagellatae in marine waters. These bodies emit bad smell, secrete certain poisonous substances harmful to aquatic animals, and also sometimes checks the speed of ships due to their presence in the form of a thick layer. The water blooms sometimes also deplete the oxygen contents of the water during night time as these act as barriers between the water and outer atmosphere so that the atmospheric oxygen cannot come in contact with the water and get dissolved in it.

iii.Death to Living Organisms

The decaying dead algal plants secrete certain poisonous by-products which are injurious to the life of the aquatic animals. Also some algae, e. g., *Microcystis aeruginosa and M. toxica* secrete toxins which cause the death of the aquatic animals including the fish. Ingestion of some of dinoflagellates like Gymnodinium, Gonyaulax and Pyrodinium cause death of a large number of fish. The water in which these species are growing also becomes poisonous and results in the death of cattles by drinking this infected water.

iv.Diseases in Human Beings

The water contaminated by *Microcystis and Anabaena* causes stomach troubles in human beings. Similarly respiratory disorders have been observed when the water infected by *Gymnodinium brevis* is taken by the humans. *Lyngbya* and Chlorella are responsible for skin diseases and some other algae cause allergies.

v.Parasitic Activities

Some algae are parasites on other plants and animals as well. Most of these belong to the Rhodophyta (red algae) and include genera like *Pterocladiophila hemisphaerica* which is parasite on *Pterolcladia lucida, and Gelidiocolax mammilata* parasitizing *Pterocladia*, etc.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are aerophytes.
2. Enlist different types of algal pigments.
3. What are aplanospores.
4. What is isogamy.
5. What are heterogamets.
6. What is haplontic life cycle.
7. What are the basis of algal classification.
8. What are water blooms.
9. What are parasitic algae.
10. What are diatomite.

B. Long Questions

1. Write note on habitat and algal pigments.
2. Describe asexual reproduction in algae.
3. Describe various life cycle found in algae.
4. What are algae? Give its classification.
5. Give economic importance of algae.

CHLOROPHYTA

The division Chlorophyta (Gr. chloros=green + phyton=plant) includes a single class Chlorophyceae (Gr. phykos=seaweeds).

GENERAL ACCOUNT OF CHLOROPHYTA

1. The members of this division are characterized by presence of grass-green chromatophores.
2. The green algae are widespread and occur both in fresh and marine waters, on moist wood and rocks, and on the surface of and within soil. A number of species are epiphytic on other algal plants, flowering plants and animals. Most of the marine species are attached to the rocks or larger algae, or growing on sandy bottoms.
3. Species like *Trebauxia, Chlorella, Coccomyxa,* etc partner fungi to form lichens.
4. The thallus ranges from a motile unicell to complex heterotrichous filamentous forms.
5. The cell is typically eukaryotic and contains pyrenoids which are thought to be concerned with starch formation.
6. The cell is bounded by a two-layered cell wall usually. In some forms the cell wall is absent. The outer layer is made up of pectin and the inner is formed of cellulose, pectin and in some cases polysaccharides are also present.
7. The cytoplasm is distinct and contains typical eukaryotic organelle, the chloroplasts, mitochondria, Golgi bodies, endoplasmic reticulum, and ribosomes.
8. The nucleus is bounded by a definite nuclear membrane and encloses nucleoli, chromosomes and karyolymph. Usually a single nucleus is present but in some genera the cells are coenocytic (multinucleate due to absence of cross walls).
9. The chloroplasts are grass-green and vary in number and shape from species to species. They contain chlorophyll a and b, alpha- and beta-carotenes and certain xanthophylls. In majority of species pyrenoids (Gr. pyren=fruit or stone) are present in the chloroplasts.
10. The reserve food is starch and stored in the plastids. The chloroplasts of motile algae and motile reproductive cells of non-motile green algae contain a reddish spot called eyespot or stigma. It is thought to be sensitive to light and directs the movement of the swimming cells.
11. Green algae reproduce by vegetative, asexual or sexual reproductive methods.
12. Majority of forms exhibit sexual reproduction ranging from isogamous to oogamous type.
13. Most of the forms have a haploid dominant phase but a few exhibit a regular alternation of generations.
14. More than 450 genera and 7500 species have been described so far.

CHLAMYDOMONAS

Kingdom: Plantae
Division: Chlorophyta
Class: Chlorophyceae
Order: Volvocales
Family: Chlamydomonadaceae
Genus: *Chlamydomonas*

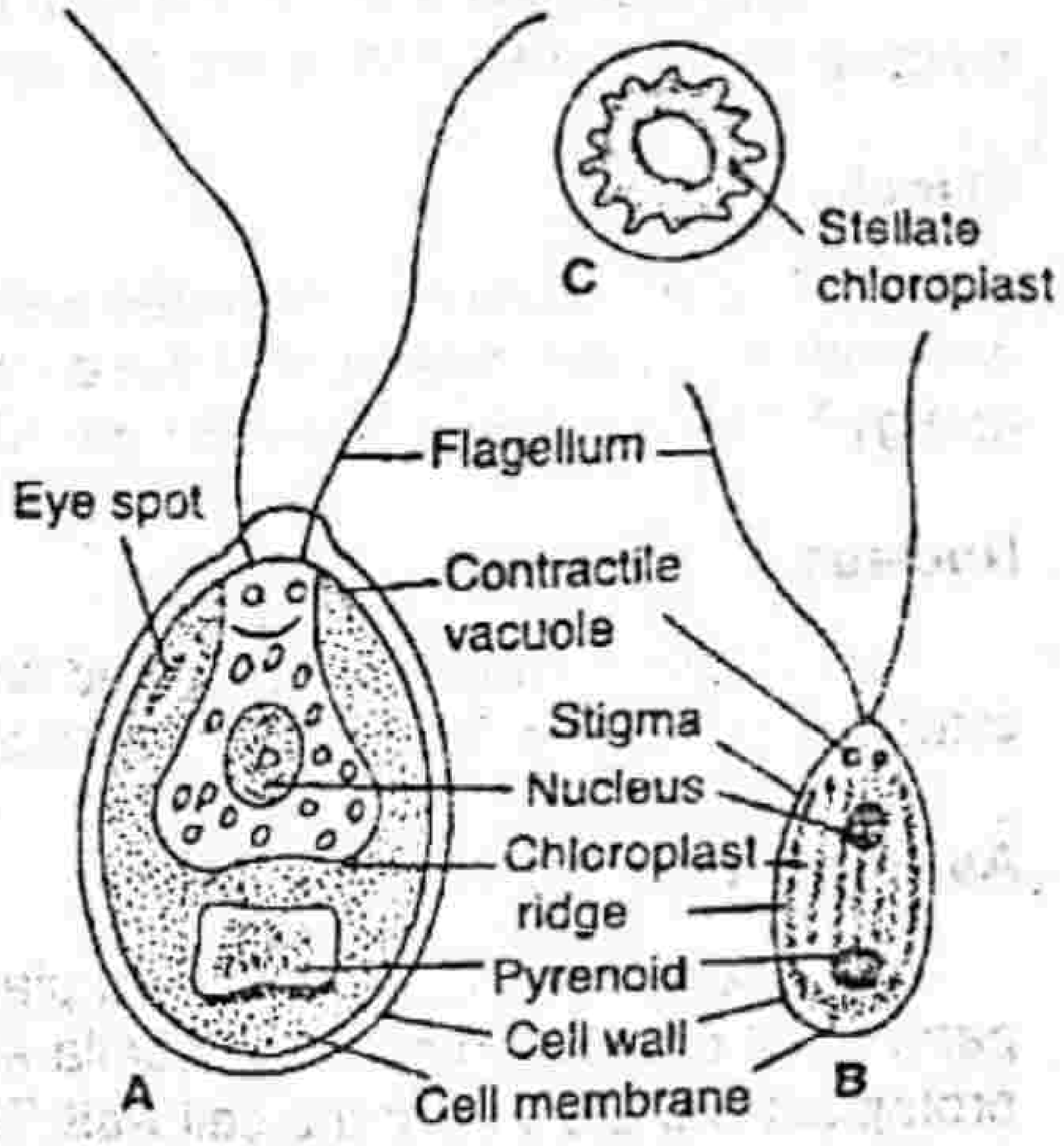


Fig. 4.5: Morphology

Occurrence

It is fresh water free swimming alga. Many species oocures in waters having, high content of organic matter. It is frequently found in standing water and ponds, ditches, pools, rain water and in damp soil.

Structure

The plant body is thallus, which consist of single biflagellated cell. It is about 10-30 micron in length. It is usually oval or oblong in shape. The cell organelles are mitochondria, dictyosomes, endoplasmic reticulum, ribosome and nuromotor apparatus.

It has the following main demarcations.

Cell Wall

The protoplast is covered by a distinct cell wall. The cell wall is thin and transparent. It is cellulose in nature, but some species also contain hemicelluloses, hydroxyproline-rich glycoproteins,

Contractile vacuole

There are two contractile vacuoles situated in the cytoplasm at her anterior end of the cell, near the base of flagellum. These contract alternatively to expel water. Its main function is osmoregulatorey.

Chloroplast .

There is a cup shaped chloroplast is present in the cell. It is a sac like structure enclosing a granular matrix called stroma. It contains the chlorophyll pigments. A pyrenoid is also present in the cell wall. The reserve food material is starch.

Eye spot

Each cell has a single eyespot towards the outer face. It is red in color. The main function of the eye spot to detect the direction and intensity of the light.

Flagella

The protoplasm is provided with two long, whip like flagella. They are of whiplash type with a 9+2 arrangement of the component fibrils. They are locomotary organ and the energy for locomotion is derived from ATP.

Nucleus

The single nucleus is located centrally, near the anterior end. It is embaded in the cytoplasm that fill in the hollow of chloroplast cup. The nucleus has a distinct nucleolus.

Asexual Reproduction

Asexual reproduction takes place by zoospore formation. In growing season the parent cell come to rest. The flagella are reabsorbed, contractile vacuole disappear and protoplast withdraw from the cell wall. The cytoplasm, chloroplast and the nucleus divided along a longitudinal plane into two daughter protoplast. Then the division comes to transverse with respect to cell as whole. In this way usually four daughter protoplast may be formed. The chloroplast is halved along with the pyrenoid at each successive division. One daughter cell receives the eye spot of parent, the other forms it afresh. The aflagellate daughter protoplast remains bound within the parent wall. These daughter protoplasts within the original cell wall look like a colony. Each daughter protoplast acquire a cell wall, develop flagella of its own, the vacuole reappear. They resembles with the parent but small in size. The parent cell wall ruptures and the daughter cell are

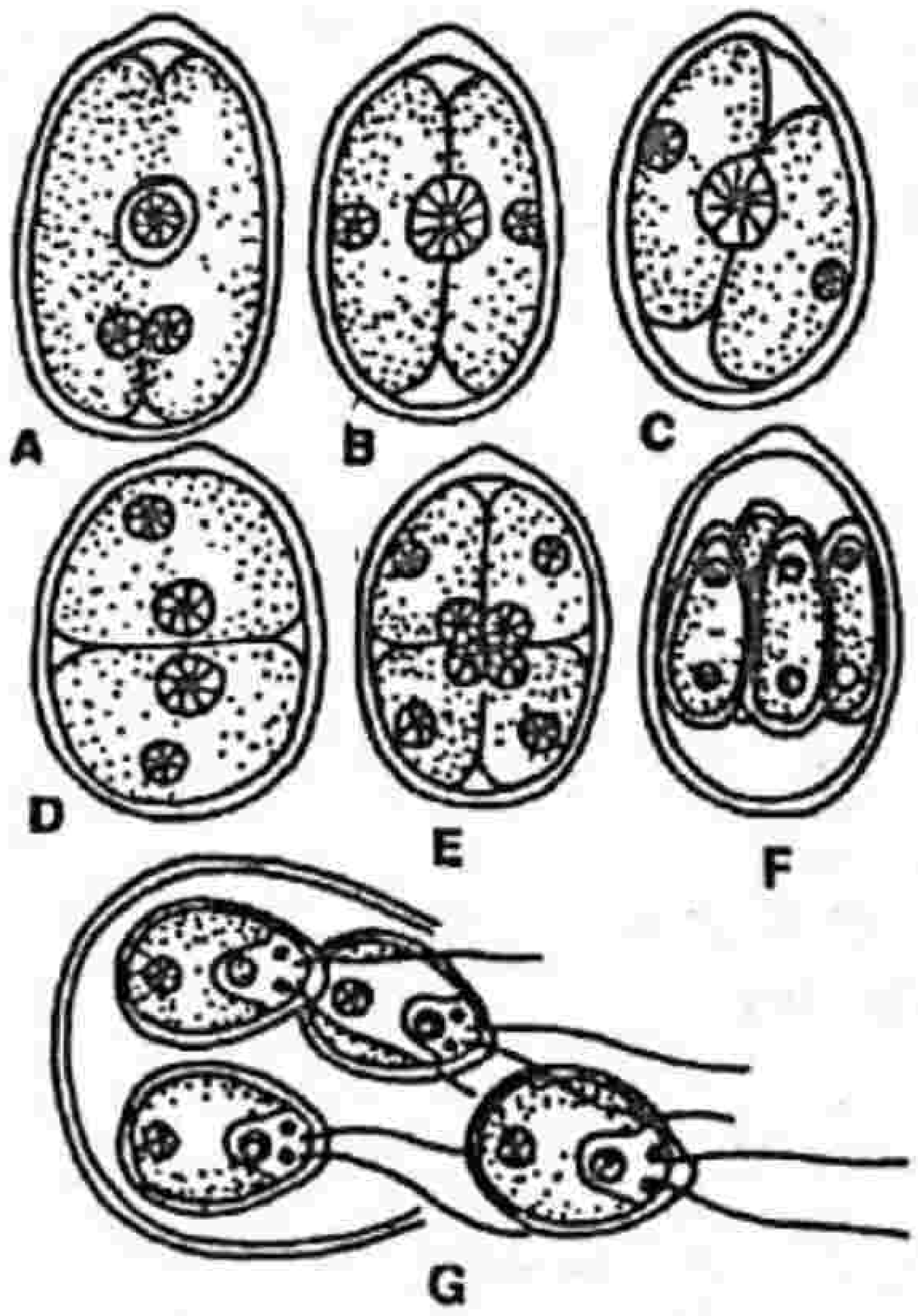


Fig 4.6: Stages in zoospore formation.

released and termed as zoospores. The daughter cells soon grow to the full size and repeat the process.

Under unsuitable conditions the motile cell come to rest and loses flagella. The protoplast divides into 4-8 cells and fail to develop flagella and fail to escape. They remain together in the parent cell wall which become mucilaginous and swell up. Each daughter cell continually divided and a colony of considerable size contain numerous cells embedded in common mucilage. This assembly of cell is known as palmella stage. When condition become suitable the cell become motile and escape from the mucilage and grow to the parent size.

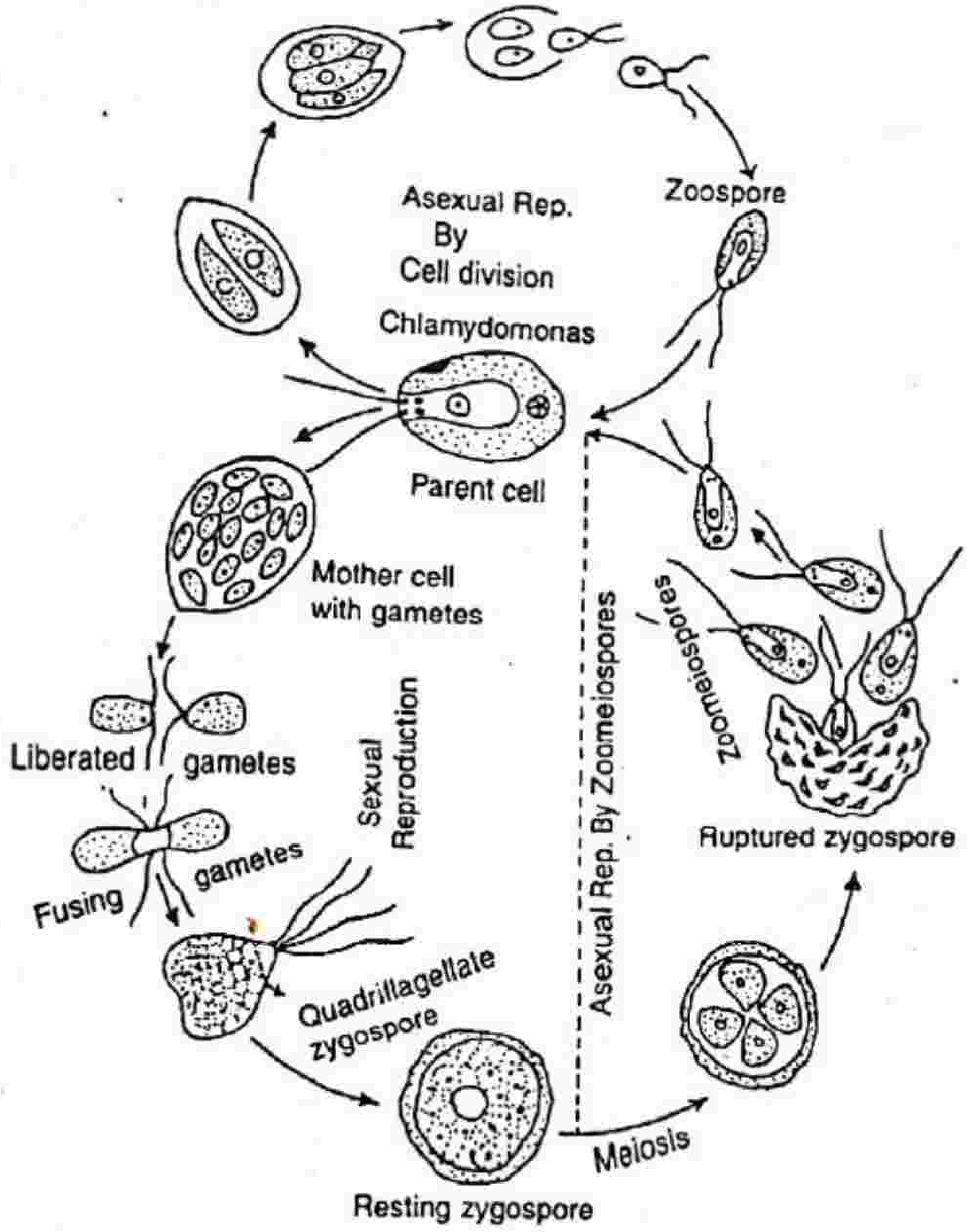


Fig. 4.7: Asexual and Sexual life cycle.

Sexual Reproduction

Sexual reproduction in *Chlamydomonas* varies through a wide range. It range from isogamy to anisogamy and even primitive type of oogamy.

In isogamy the fusion of gametes similar in size , form and structure and thus are called the isogametes. The sexual fusion takes place between biflagellate gametes coming from the same parent cell. The fusion gametes are motile, naked and smaller in size. At the time of gamete formation the cell withdraws its flagella and comes to rest. The protoplast of cell then divided to form 16, 32, or 64 daughter protoplast. It is pear shape in form and has no cell wall. The gametes release in water and swim for a while. Finally they come near each other and fuse in pairs either end to end or side by side. The cytoplasm and nucleus fuses with each other. They come to rest, retracts its flagella, rounds up and secretes a thick wall around it to become a zygospore. It tide over unfavorable conditions.

When the conditions become suitable it become germinate. The diploid nucleus undergoes meiosis to form four haploid nuclei. The haploid nuclei are eventually incorporated into meiospore which are motile. At this stage the zygospore wall crakes liberating the spores having two flagella. The meiospore then grow to an adult *Chlamydomonas* cell.

①Classification:-

VOLVOX

DCO
FG

Taxonomic Position

Division:	Chlorophyta
Class:	Chlorophyceae
Order:	Volvocales
Family:	Volvocaceae
Genus:	*Volvox*

② Habitat:-

The Volvox (L. volver=to roll) is a green, flagellated, colonial alga found in both temporary and permanent water ponds, pools and ditches. It usually grows in spring and summer but abundant growth takes place during rainy season. The colonies are found in the form of small balls of the size of a pin-head which are visible to the naked eye. It passes winter in resting condition as oospore or zygospore.

③ PLANT BODY

Colony

The Volvox colony is in the form of a hollow sphere having a definite number of cells arranged at its periphery in a single layer. The interior of the colony is filled with watery mucilage. Such a colony is called a coenobium. The number of cells vary from 500-50,000. Each cell is biflagellate and the flagella project outward to the surface of colony. Each cell of the colony is surrounded by a mucilaginous sheath of its own and all the cells of the colony are connected to each other with the help of a series of broad protoplasmic strands.

④ Cell Structure

Each cell is surrounded by a mucilaginous sheath. All the cells in the colony are similar in shape. The structure of each cell is resembled with the Chlamydomonas. The cells are pear shaped containing a cup shaped chloroplast. Only one pyrenoid is present on the chloroplast. There are two contractile vacuoles near the pointed end. The single nucleus is located in the center. Each cell has a single eyespot towards the outer face. The eyespot of the cells located at the anterior of the colony is better developed than the posterior one. The cells of the colony are joined together by delicate cytoplasmic strands.

⑤ Reproduction:-

The Volvox reproduces asexually when the season is favourable and sexually when the growing conditions become unfavourable.

Asexual Reproduction

Few posterior cells of a mature colony enlarge in size, become more or less rounded, withdraw their flagella and are pushed back into the colony. The nuclei and protoplasmic contents of these cells are more prominent than the surrounding cells. These cells are called gonidia and are responsible for the development of the daughter colony.

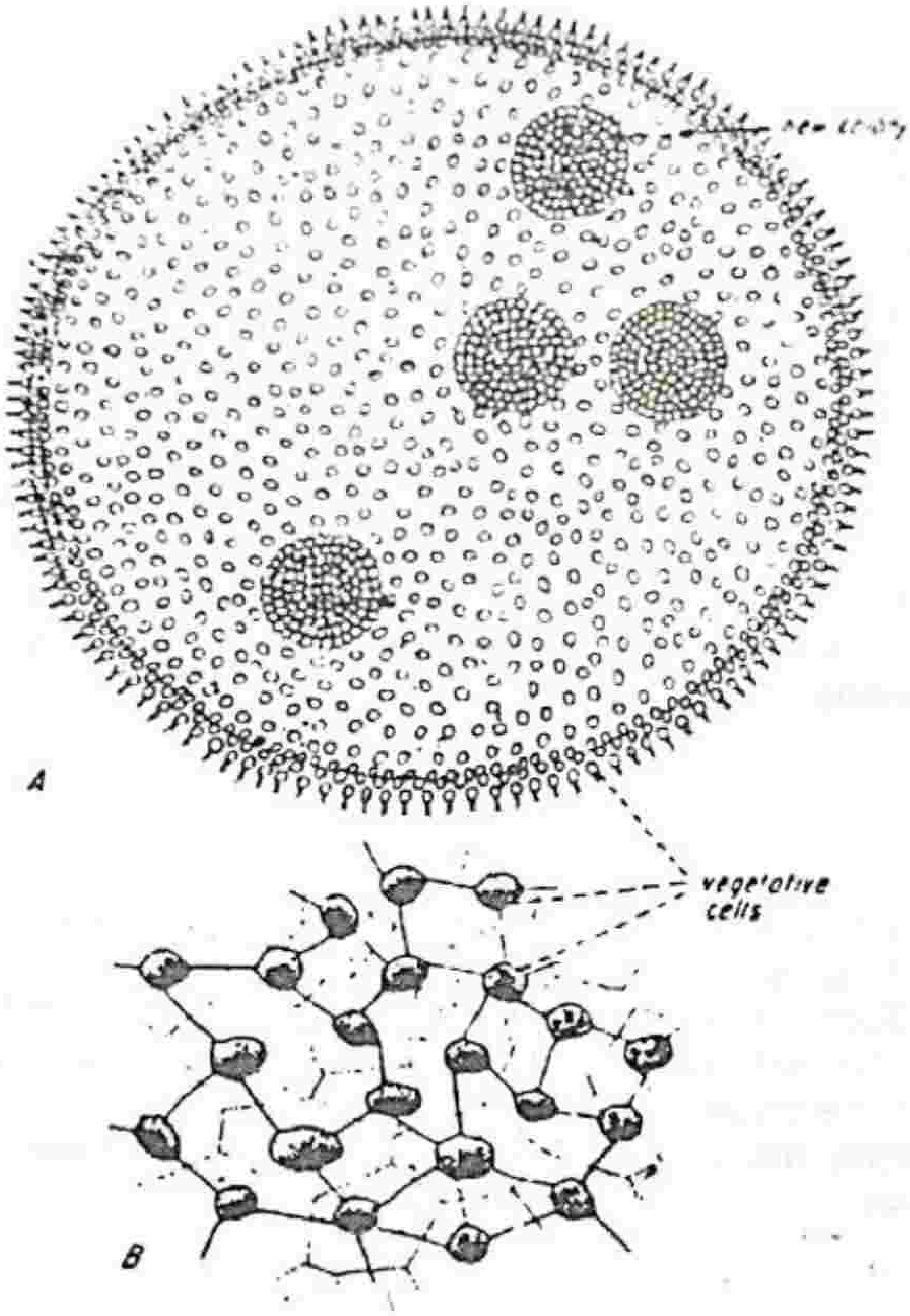


Fig. 4.8: Volvox —Morphology of a colony and structure of a cell.

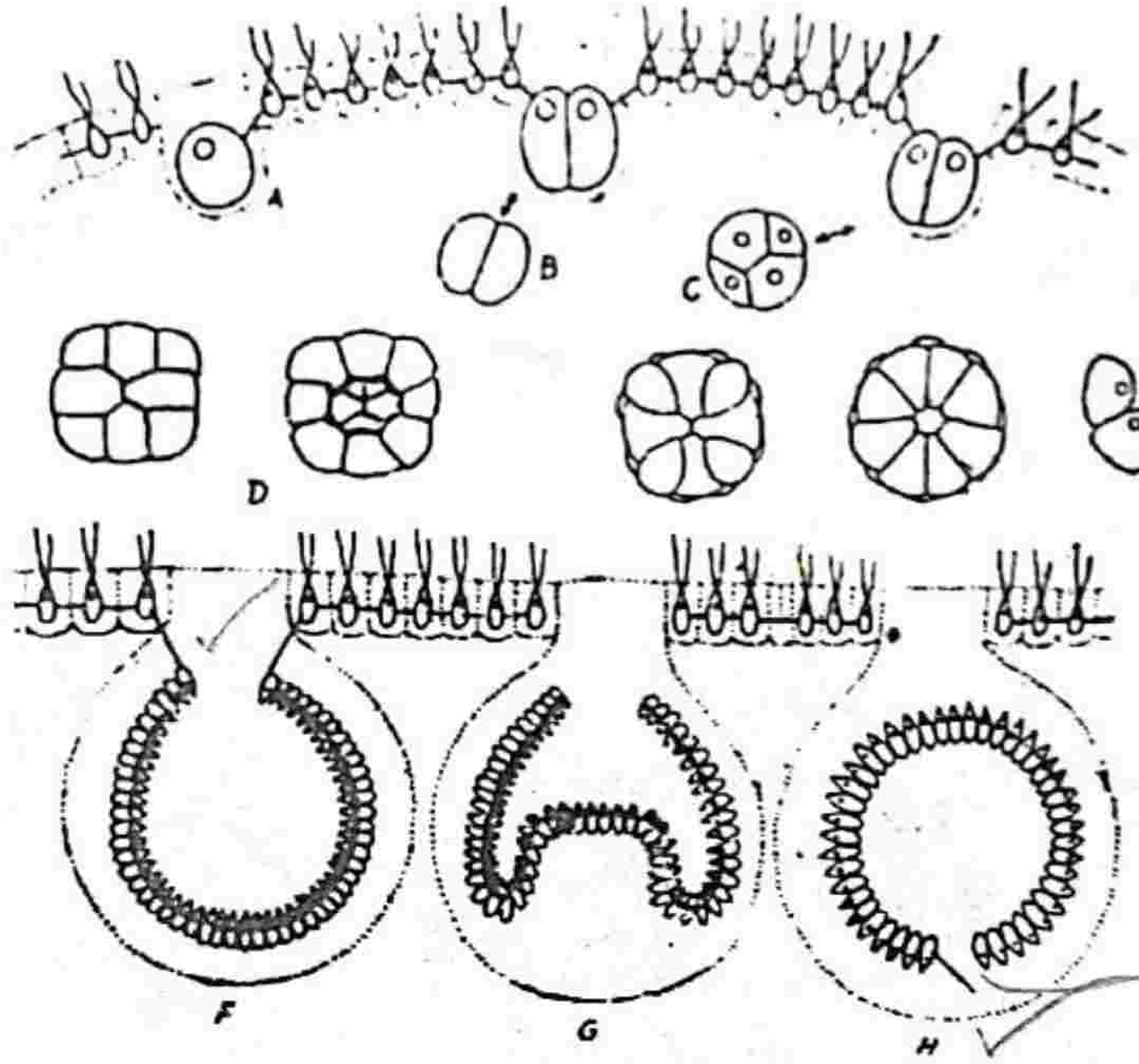
The following stages are involved in the development of a daughter colony.

i. The gonidium divides by two vertical divisions at right angles to each other to form four daughter cells. These cells divide further by a vertical division to form an eight-celled plakea stage. The cells are arranged in the form of an incurved plate with concave surface outside.

ii. Another vertical division results in the formation of 16 cells arranged in the form of a hemisphere. Further divisions in the same plane result in the formation of hollow sphere with a pore, the phialopore.

iii. The vertical divisions of daughter cells continue till the specific number of cells for a species is produced. Uptill this stage all the cells are without mucilaginous sheaths and their anterior ends face towards the centre of the sphere.

iv. Now the inversion of the daughter colony takes place. A slight constriction just opposite phialopore marks the beginning of inversion. This invagination moves inward into the anterior half of the young coenobium and the philaopore enlarges in size greatly and its edges curl backwards. The movement continues until the whole structure is inverted through the phialopore.



(hollow at outsides)

Fig. 4.9: Volvox — Asexual reproduction.

v. At the end of inversion the anterior ends of the cells face towards the outer side. All the cells now acquire a cell membrane, develop flagella and secrete their own mucilaginous sheaths to become separated from each other.

Several daughter colonies develop within a parent colony. These colonies are set free by the disintegration of the cells of the parent colony.

Sexual Reproduction

The sexual reproduction in Volvox is strictly oogamous. Some species are monoecious (Volvox globator) while the others are dioecious. Most of the monoecious species are protandrous, i. e., the antheridia develop first. Some cells in the posterior region of the coenobium enlarge in size, withdraw their flagella and their nuclei and cytoplasmic contents become more conspicuous. These cells are called androgonidia/ and gynogonidia and are responsible for the development of antheridia and oogonia respectively.

(male/sperm)

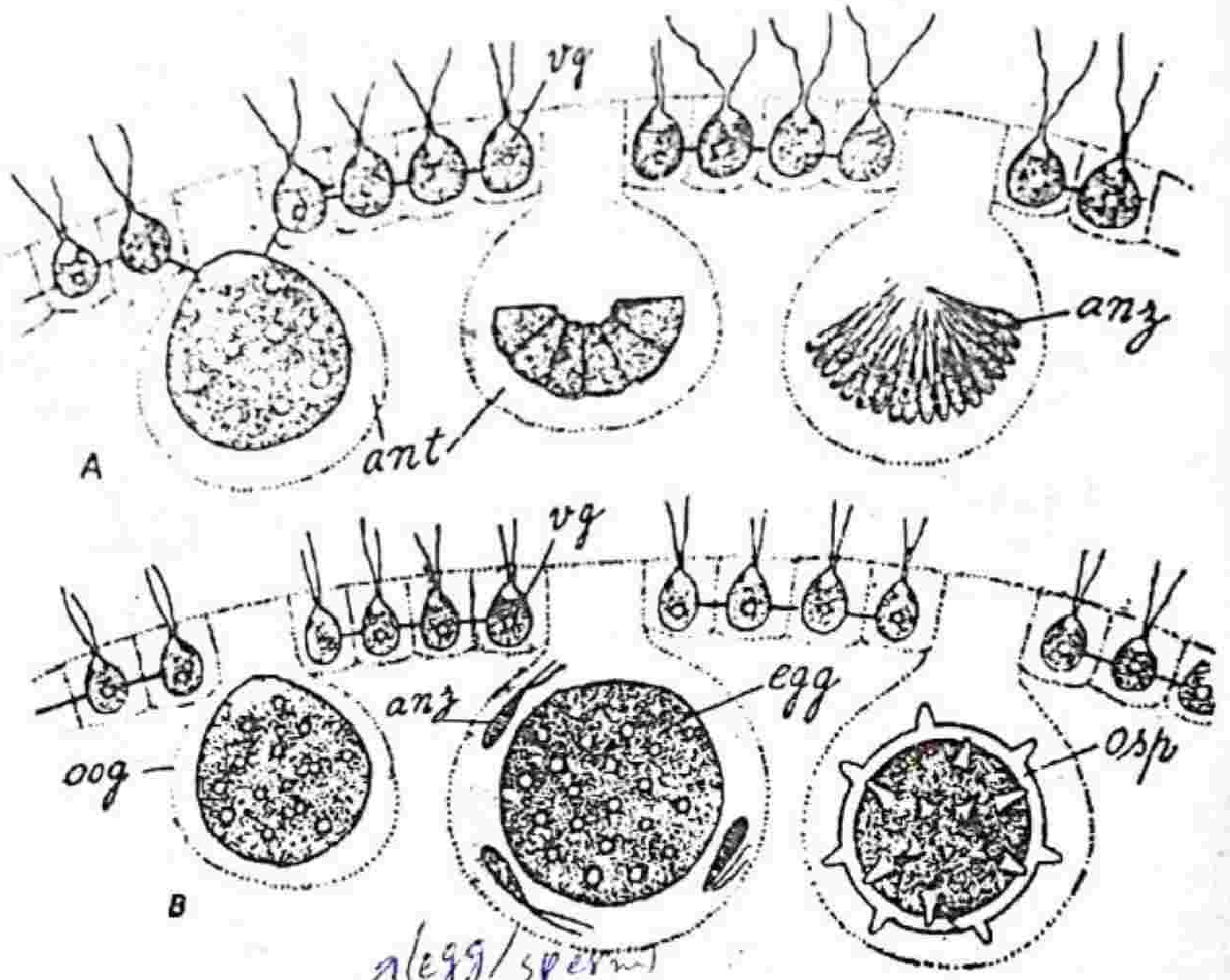
sperm cell

gynogonidia (female)

(♂ gamates)

Development of Antheridium

The protoplast of the androgonidial cell divides by successive vertical divisions to form a group of 64-128 cells. The anterior ends of the cells face inward the hollow sphere. This group of cells undergoes inversion and after the inversion the anterior ends of the cells face outside. Each cell of the group is uninucleate; long, narrow, conical or fusiform; and without mucilaginous sheath. The cells develop two flagella at their anterior ends to become antherozoids.



/egg/sperm

Fig 4.10: Volvox — Development of antherozoids& oogonium.
(♀gametes)

Development of Oogonium

Archigonia (change — shapes)

The gynogonidial cell becomes rounded or flask-shaped and functions as oogonium directly. The protoplast of the oogonium metamorphoses into a single, non-motile, spherical, uninucleate egg. It has a parietal chloroplast with many pyrenoids embedded in it and contains a large amount of reserve food. The egg usually develops a beak-like protrusion, the receptive spot, which probably marks of place of entry of the male sperms.

Fertilization

The entire mass of the male sperms is released from the antheridium and swim towards the oogonium due to chemotactic stimulation. A few male sperms enter the oogonium but only one succeeds in entering the egg through the receptive spot.

Development of Zygote

The diploid zygote secretes a three-layered smooth or spiny wall around it. It is liberated from the parent colony after its disintegration and germinate at the return of favourable conditions.

The nucleus of the zygote divides meiotically into four haploid nuclei out of which three disintegrate. The inner wall of the zygote protrude out in the form a vesicle. The haploid protoplast of the zygote migrates into this vesicle and develops two flagella to become a meiospore. This meiospore undergoes repeated divisions till the formation of characteristics number of cells of a new colony in the same manner as in the case of formation of asexual daughter colony. The coenobia formed as a result of sexual reproduction are of small size.

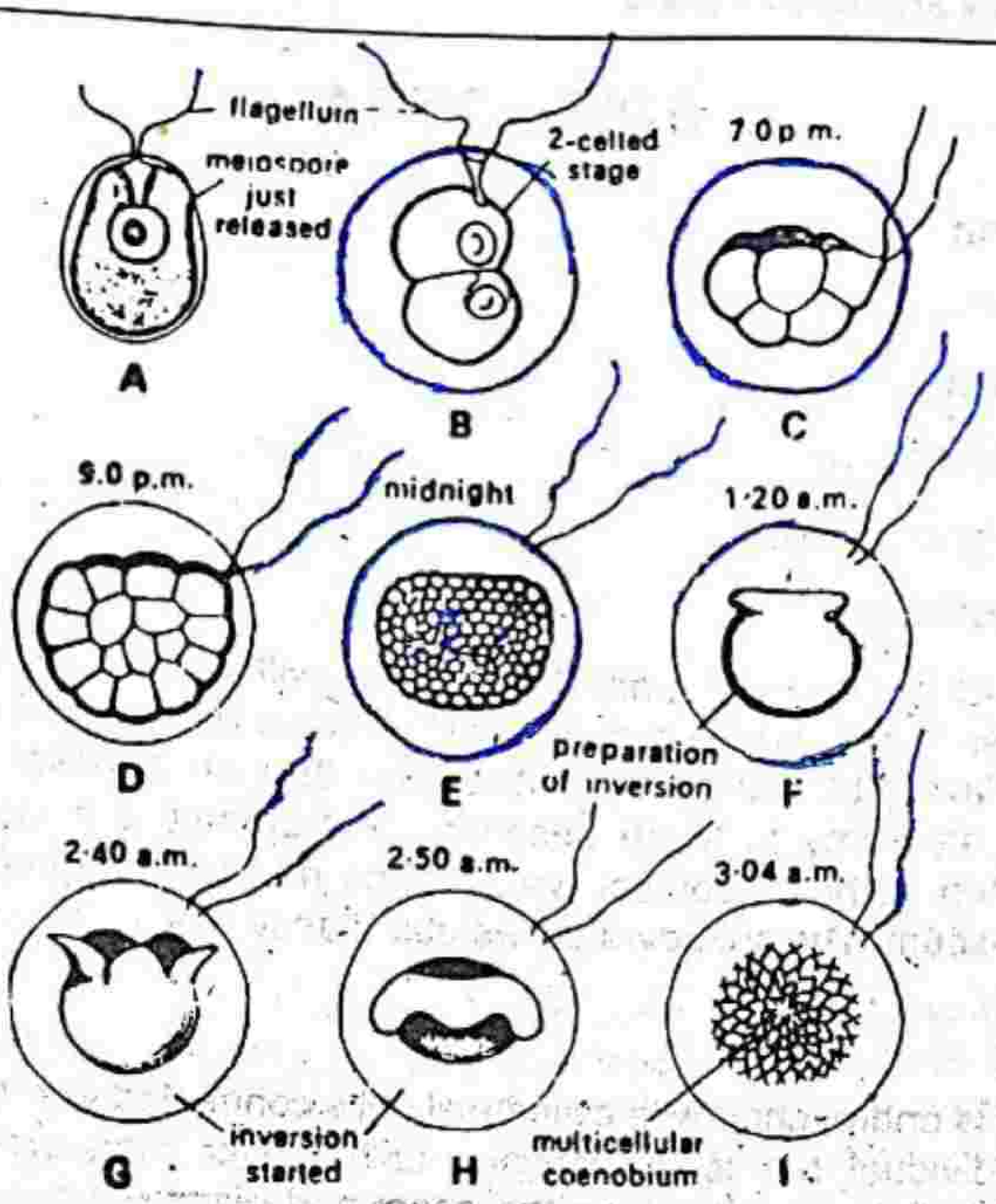


Fig. 4.11: Volvox — Successive stages during germination of zygote.

Alternation of Generations

The zygote is the only diploid phase in the life cycle of the Volvox and the main plant body is haploid, therefore it exhibits haplontic life cycle.

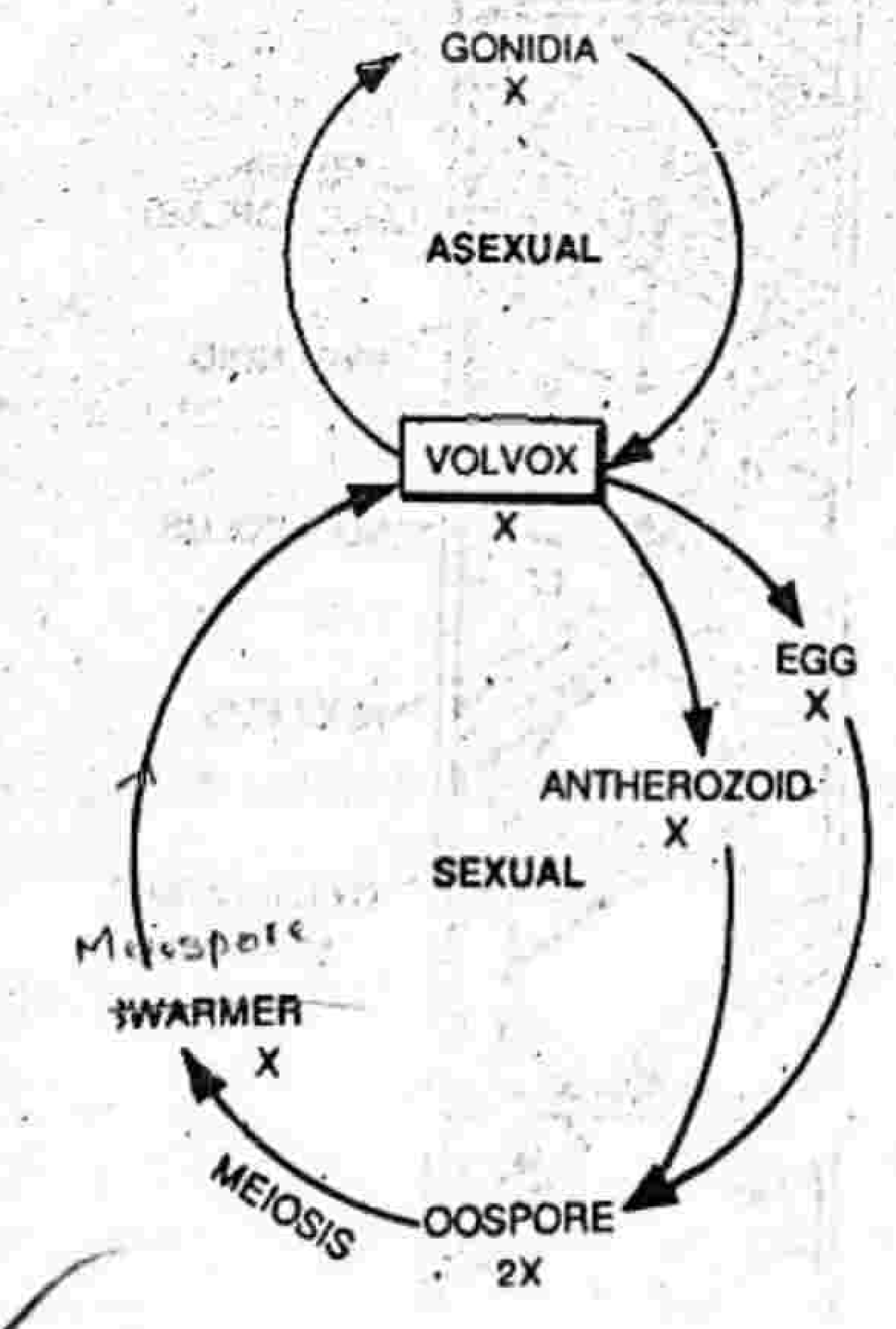


Fig. 4.12: Volvox — Graphic life cycle.

SPIROGYRA

Taxonomic Position

Division: Chlorophyta
Class: Chlorophyceae
Order: Zygnemales
Family: Zygnemaceae
Genus: *Spirogyra*

It is one of the commonest and large genus with about 300 species growing as free floating masses in stagnant or slowly moving waters (streams). Some species, e. g., *Spirogyra adnata* are attached to the substratum through a basal rhizoidal cell. The masses of plants are slimy to touch because the filaments are surrounded by pectic sheaths which when come in contact water forms mucilage, therefore it is known as water-silk or pond-scum. The spirogyra grows abundantly in spring.

PLANT BODY

Spirogyra is unbranched with cylindrical cells connected end to end in long green filaments. The individual cell is cylindrical, much longer than broad. In free-floating species there is no distinction between the basal and distal ends, whereas in attached forms the lowermost cell develops a rhizoidal outgrowth called holdfast which helps in attachment.

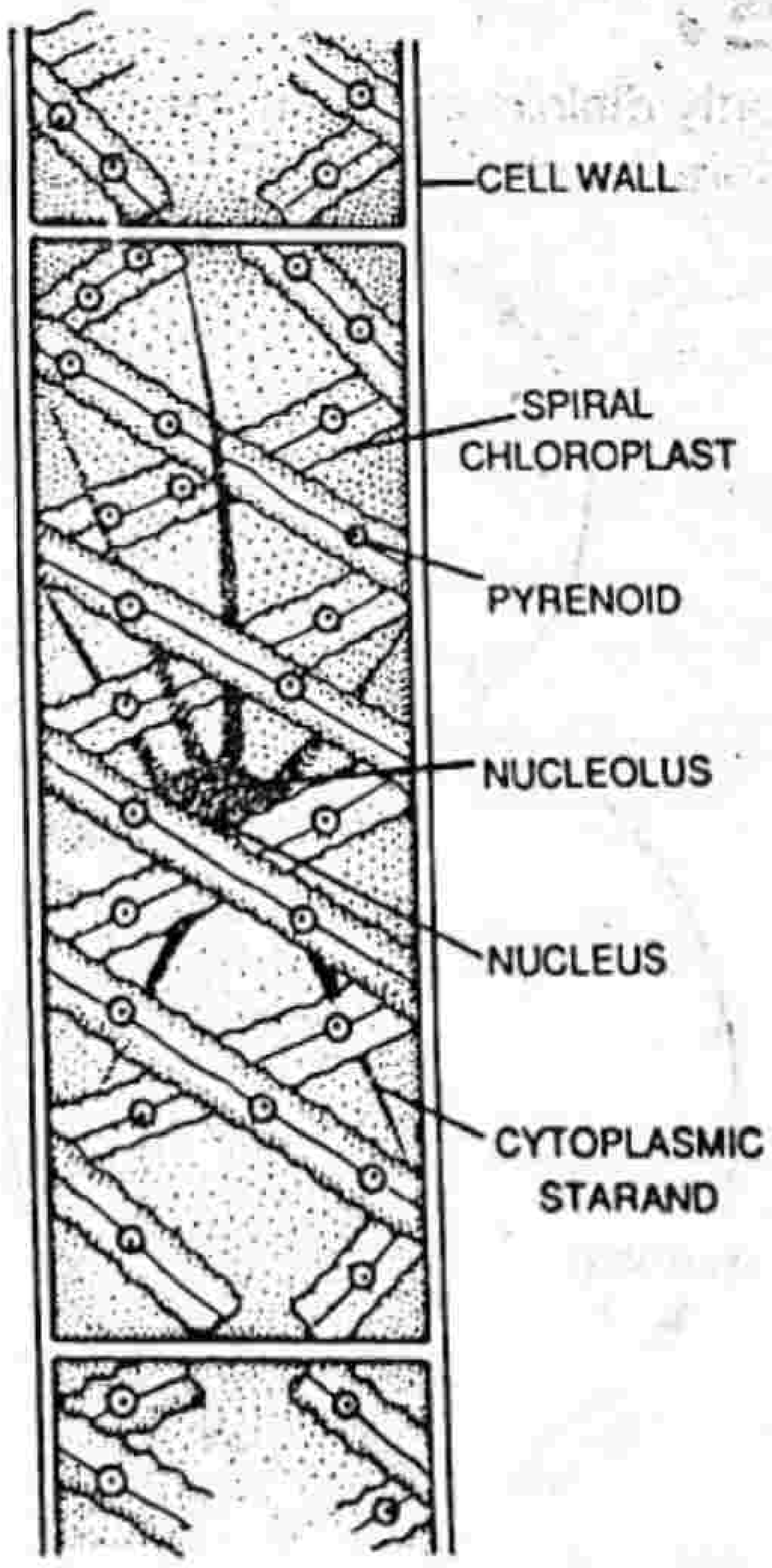


Fig. 4.13: Vegetative structure

Cell Structure

Cell wall

Each cell has a well developed cell wall. The cell wall has two layers: the outer wall is composed of cellulose while the inner wall is of pectin.

Cytoplasm

The cytoplasm forms a thin lining between the cell wall and the large vacuole. Electron microscopic studies show that mitochondria, endoplasmic reticulum, dictyosomes and other cytoplasmic inclusions are also present in the cell. The number of chromosomes vary from species to species from 5-24.

Nucleus

Each cell has a prominent nucleus in the center, suspended by thin strands of cytoplasm from the inner part of the cell wall.

Chloroplast

Chloroplasts are embedded in the peripheral cytoplasm and their numbers are variable (as few as one). The chloroplasts are ribbon shaped, and spirally arranged, resulting in the prominent and characteristic green spiral on each filament. Each chloroplast contains several pyrenoids, appearing as small round bodies. The characteristic pigments are chlorophyll a, b, c, and d, carotene and xanthophylls.

Growth

The growth of filament can take place by cell division of any cell of the filament except the holdfast.

Reproduction

The reproduction in Spirogyra is vegetative and sexual mostly. However, some species exhibit asexual reproduction.

Vegetative Reproduction

In asexual reproduction, fragmentation takes place, and *Spirogyra* simply undergoes intercalary mitosis to form new filaments. There is no asexual spores in this species.

Sexual Reproduction

The sexual reproduction occurs when the conditions are unfavourable for growth. It is primitive type of isogamous sexual reproduction called conjugation.

Mechanism of Conjugation

During the process two filaments come near each other and become glued together by their mucilage. Papillate (finger-like) outgrowths arise from the lateral walls of the cells. These papillae meet and their common walls dissolve to form a tube-like structure, the conjugation tube. The protoplast in each cell rounds off due to loss of water to form a gametes. The gametes are isogametes, however one gamete is active and move from one filament to the other. It is called male gamete. The other gamete is passive and remains in the cell. It is called female gamete. Therefore, Spirogyra exhibit physiological anisogamy. All the gametes in a conjugating filament may be either male or female. The male gametes moves towards the female gamete through conjugation tube. The protoplast and nuclei of both the gametes unite to form a diploid zygote which secretes a thick wall to become a zygospore. After a period of rest the zygospore germinates into a new filament by cell division. Low nitrogen supply and high light intensity usually stimulate sexual reproduction.

The conjugation may be scalariform conjugation or lateral conjugation:

i. Scalariform Conjugation:

It is the most common type of conjugation and occurs between opposite cells of the neighboring filaments as described above.

ii. Lateral Conjugation:

In lateral conjugation, gametes are formed in a single filament. Two adjoining cells near the common transverse wall give out protuberances known as conjugation tubes, which further form the conjugation canal upon contact. The male cytoplasm migrates through the conjugation canal, fusing with the female. The rest of the process proceeds as in scalariform conjugation.

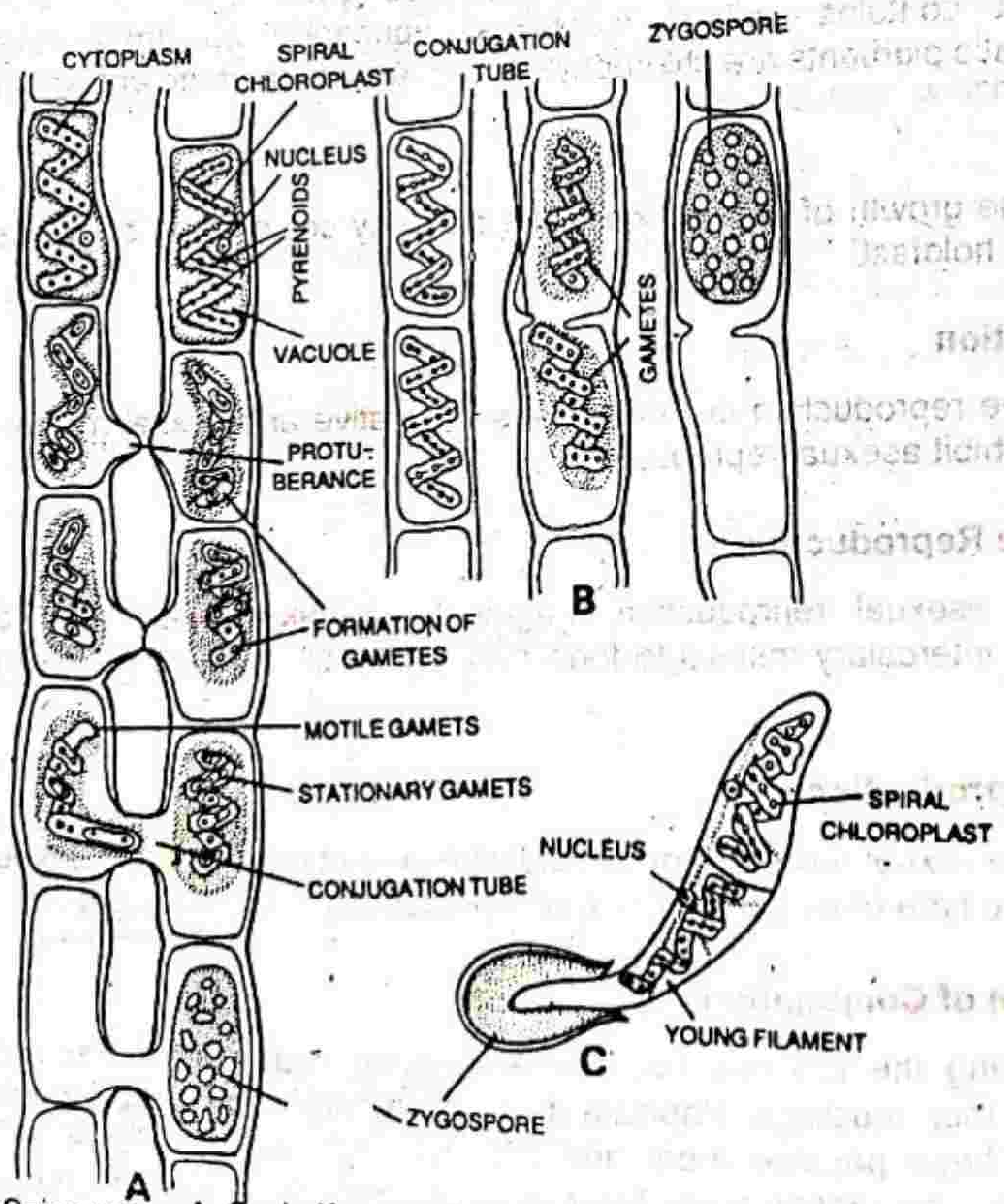


Fig. 4.14: Spirogyra — A. Scalariform conjugation; B. Lateral conjugation; C. Development of zygospore.

Structure and Development of Zygospore

The zygospore wall is 3-layered. The outermost layer is cuticularized whereas the innermost is thin and cellulosic. It is spherical or ellipsoidal and diploid. The zygospore becomes red in colour due to disintegration of chloroplast, accumulation of oil and development of haematochrome. The zygospore is liberated by the decay of the wall of the female gametangium. It settles down to the bottom of the water and undergoes a long period of rest.

Germination of Zygospore

At the return of favourable conditions the zygospore germinates. The nucleus of the zygospore divides meiotically into four haploid nuclei. Three of these degenerate and the fourth one remains functional. The two outer layers burst and the innermost thin layer protrudes out in the form of a germ tube. This tube elongates and divides transversely into a colourless cell which functions as rhizoidal cell and attaches the germ tube to some support, and an upper green cell. The upper cell divides repeatedly to produce an adult filament which detaches itself from the support and floats freely in water.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What is the importance of eye spot in Chlamydomonas.
2. What is the taxonomic position of volvox.
3. Why spirogyra is so called.
4. What is lateral conjugation in spirogyra.
5. What is heterotrichus form in chlorophyceae.
6. What is fragmentation.
7. What is daughter colony.
8. What is zygospore. Give its importance.
9. Describe asexual reproduction in volvox.
10. What is vegetative reproduction.

B. Long Questions

1. Describe structure and reproduction of Chlamydomonas.
2. Describe structure andasexsual reproduction in volvox.
3. Describe life cycle of volvox.
4. Describe conjugation in spirogyra.
5. Describe morphology of spirogyra.
6. Describe structure and development of zygospore in spirogyra.

CHAROPHYTA

The green algae included in this division was once classified in Chlorophyta as a class Charophyceae, but now raised to the status of division. The genera included in Charophyta are very much different from the members of Chlorophyta morphologically and in some other characteristics.

1. The plant body is macroscopic and resembles those of Arthrophyta.
2. The plant body is differentiated into nodes and internodes. The nodes bear whorls of branches of limited growth are present that resemble the leaves of angiospermic plants.
3. The development of plant body is from a single apical cell
4. The cells are prokaryotic, long, uninucleate, contain discoid chloroplasts, and are bounded by cellulosic cell wall.
5. The protoplasm show a rapid streaming movement parallel to the long axis of the cell.
6. A prominent large central vacuole occupies the center of the internodal cells, therefore, the cytoplasm is peripheral.
7. The nucleus occupies center of the cell.
8. The reproduction in Charophyta is vegetative and sexual.
9. The vegetative reproduction is by:
   i. **Amylum Stars:**These are star-shaped aggregates of cell developed from the lower nodes. They are densely filled with starch.
   ii. **Bulbils:**These are bodies with food stored in them called that develop upon rhizoids.
   iii. **Protonema**like outgrowths that develop from the nodes.
10. The asexual reproduction by the formation of spores is absent.
11. The sexual reproduction is strictly oogamous and the gametes are produced in specialized complex structures, the globules (antheridium) and nucules (oogonium).
12. So far 7 living genera with about 294 species have been recorded. These are *Chara* (27 species), *Tolypella* (3 species), *Nitella* (37 species), *Nitellopsis* (a single species), *Lychnothamnus* (a single species), *Lamprothamnium* and *Protochara*.

CHARA

① Classification:-

Taxonomic Position

DCO
FG

Division: Charophyta
Class: Charophyceae
Order: Charales
Family: Characeae
Genus: *Chara*

② Habitat:-

Chara grows submerged in fresh water and upon muddy or sandy bottoms of pools and ponds, or in limestone streams. Certain species have the capacity of precipitating calcium carbonate from the water and covering themselves with calcareous layers. Clear hard water is suitable for their growth. Mature plant is enriched with $CaCO_3$. therefore, they are called as stone worts.

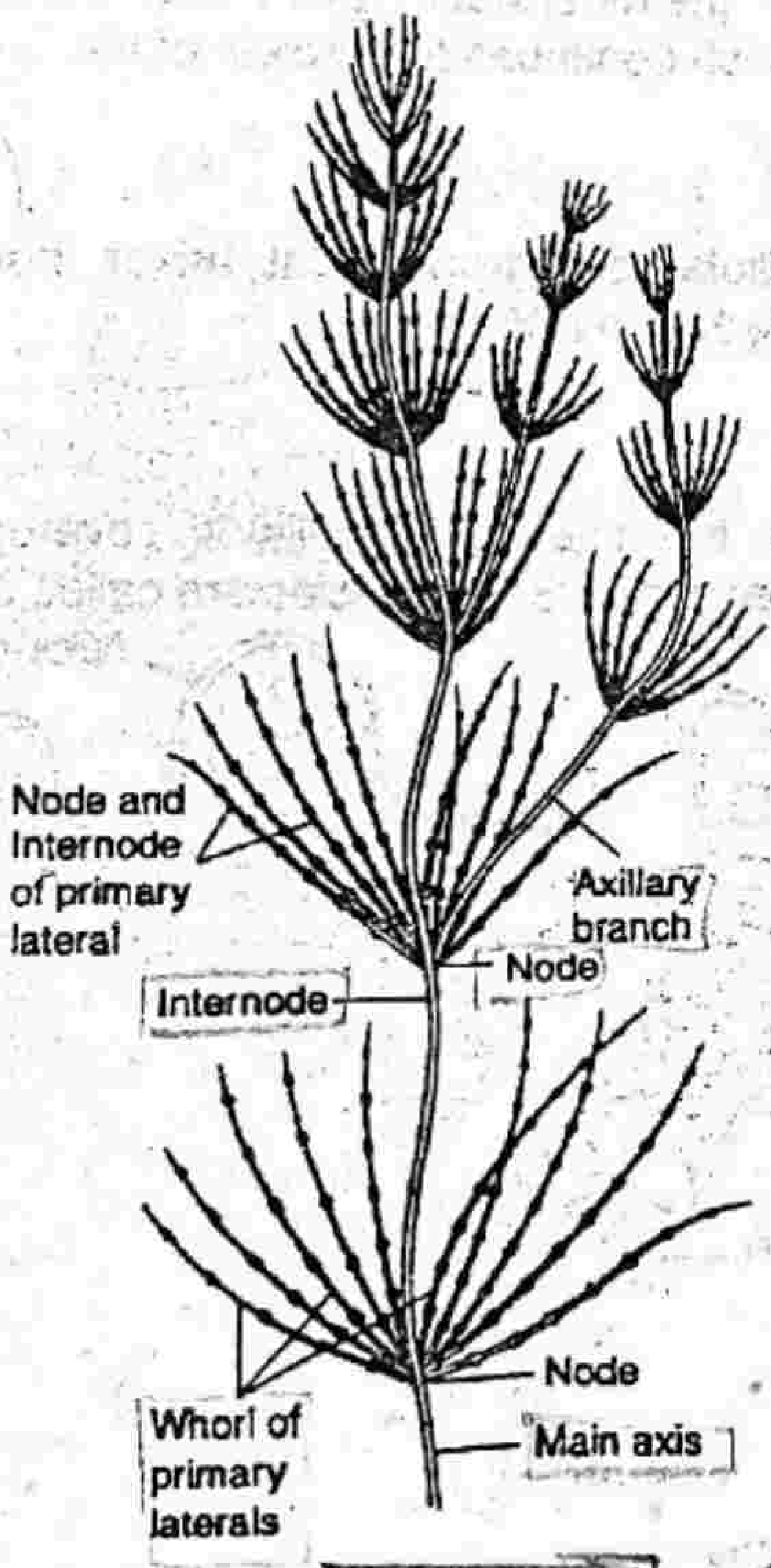

Node and Internode of primary lateral
Axillary branch
Node
Internode
Node
Main axis
Whorl of primary laterals

Fig. 4.14: A chara plant

③ PLANT BODY

Thallus

The plant body is thallus. The plant attains a height of 20-30cm. It has following demarcations.

(long)

Rhizoids

The thallus is erect, branched structure attached to the substratum by means of rhizoids.

Branches

The thallus has long, slender upright branches. The axis is differentiated into node and internodes. From each node arise the following four type of appendages.

1. Branchlets

Each node bears a whorl of branches, which has limited growth. These are called branchlets.

2. Long Branches

There are one or two branches of unlimited growth may also be present in each node. They arises singly at the older nodes of the main axis. They often called as axillary branches. The axillary branch continues the growth of thallus.

3. Stipuloids

(for making support)

These are unicellular out growth that arises from the basal node of each branchlet. They are usually two in number.

4. Cortex

In some species the intermodal cells is covered by a sheath of vertically elongated narrow cells, the cortex. Such species are called as corticated.

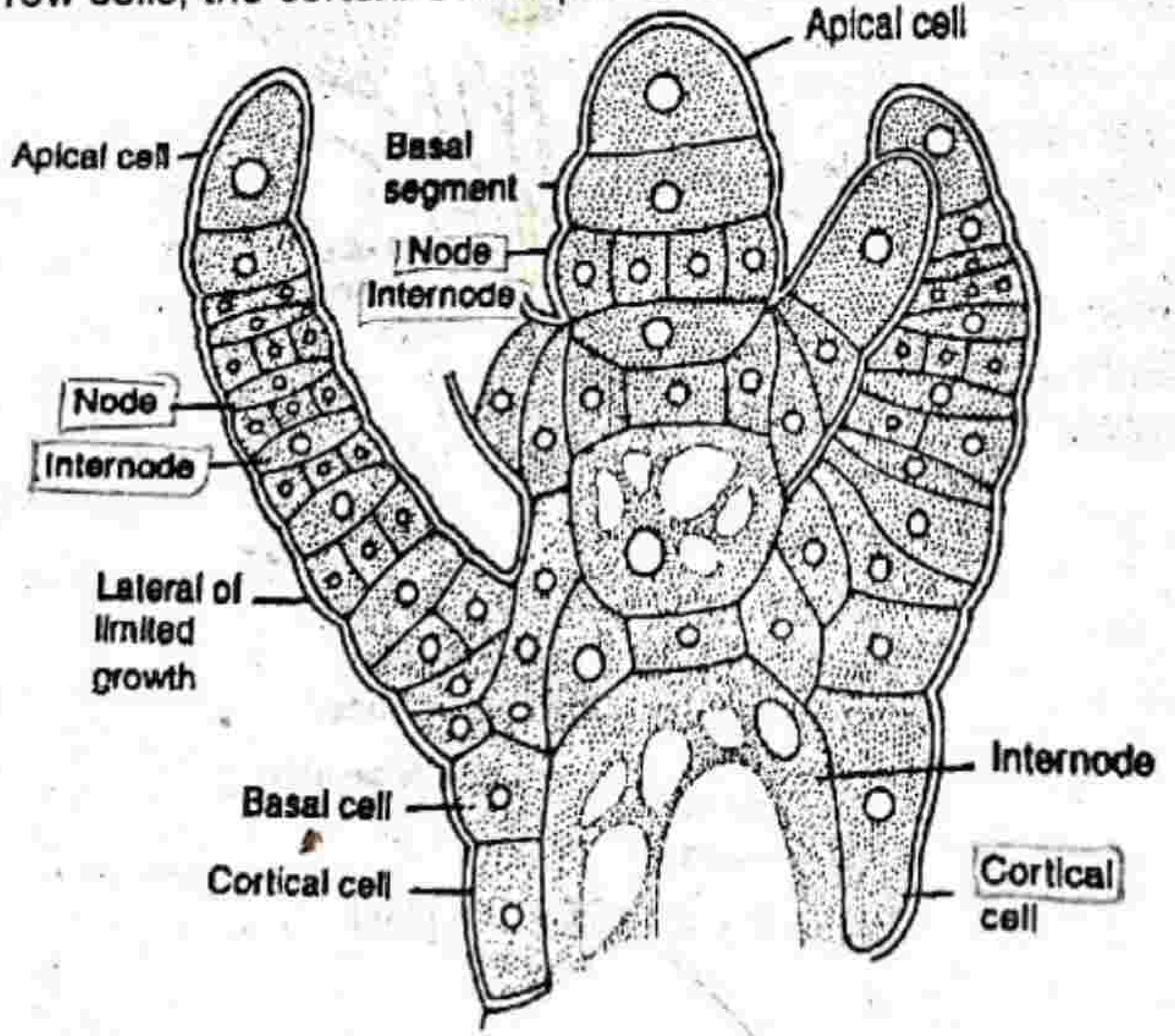


Fig. 4.15: V.S. of Apical portion of thallus.

④ Cell Structure

Young cells are always uninucleated structures without conspicuous vacuole. In the mature cells the vacuole may be developed and may become multinucleated due to amitosis. There are many small ellipsoidal chloroplasts arranged longitudinally in peripheral portion of cytoplasm. The cell wall of the internodal cell is impregnated with silica and calcium carbonate. The reserve food material is starch and the cytoplasm show characteristics cyclic movement.

④ Growth of the Thallus

The growth of the thallus is by dome-shaped apical cell which cuts off derivatives at its posterior surface. Each derivative undergoes a transverse division to produce two daughter cell. The upper cell acts as nodal initial and the lower as internodal initial. The internodal initial elongates many times its original length and matures to form internode of the axis. The nodal initial divides by vertical divisions intersecting each other to produce two central cells surrounded by 6-20 peripheral cells. Each peripheral cell cuts off apical cells of branches of limited growth.

(Apix ⇒ tip)

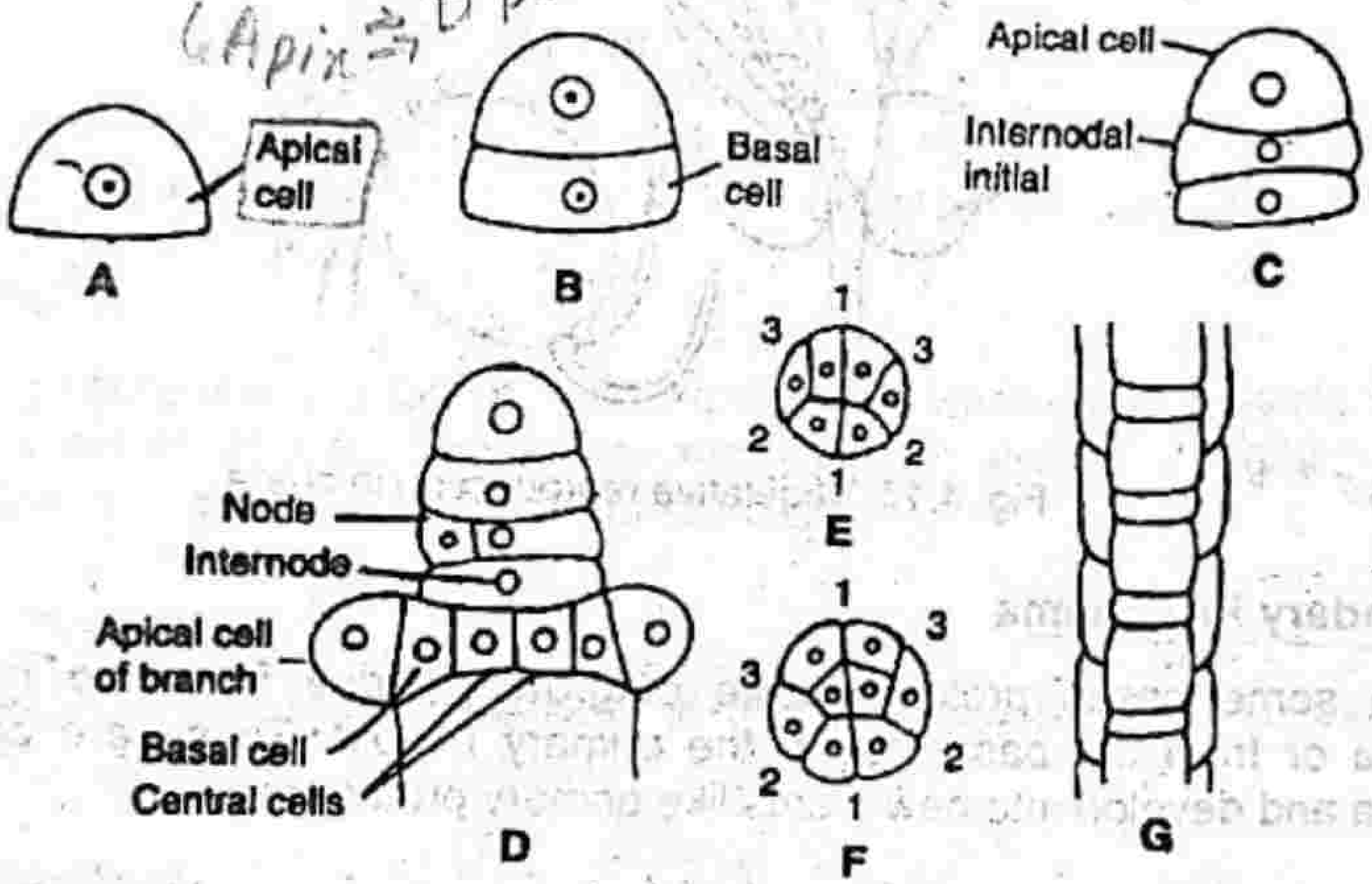


Fig. 4.16: Chara — Growth of the thallus.

⑤ Reproduction

The Chara reproduces by vegetative and sexual reproduction. Asexual reproduction by spore formation is absent.

Vegetative Reproduction

The vegetative reproduction in Chara involves various kinds of reproductive bodies which on detachment from the parent plant give rise to a new plant. The common means of vegetative reproduction are as followings:-

i. Amylum Stars:

These are star-shaped groups of cells developed from the lower nodes. The cells contain amylum starch. After being detached these develop into new plants.

ii. Bulbils

These are small, rounded or star-shaped, tuberous bodies that develop either on rhizoids (Chara aspera) or on stem nodes (Chara baltica). These develop into new plant on detachment.

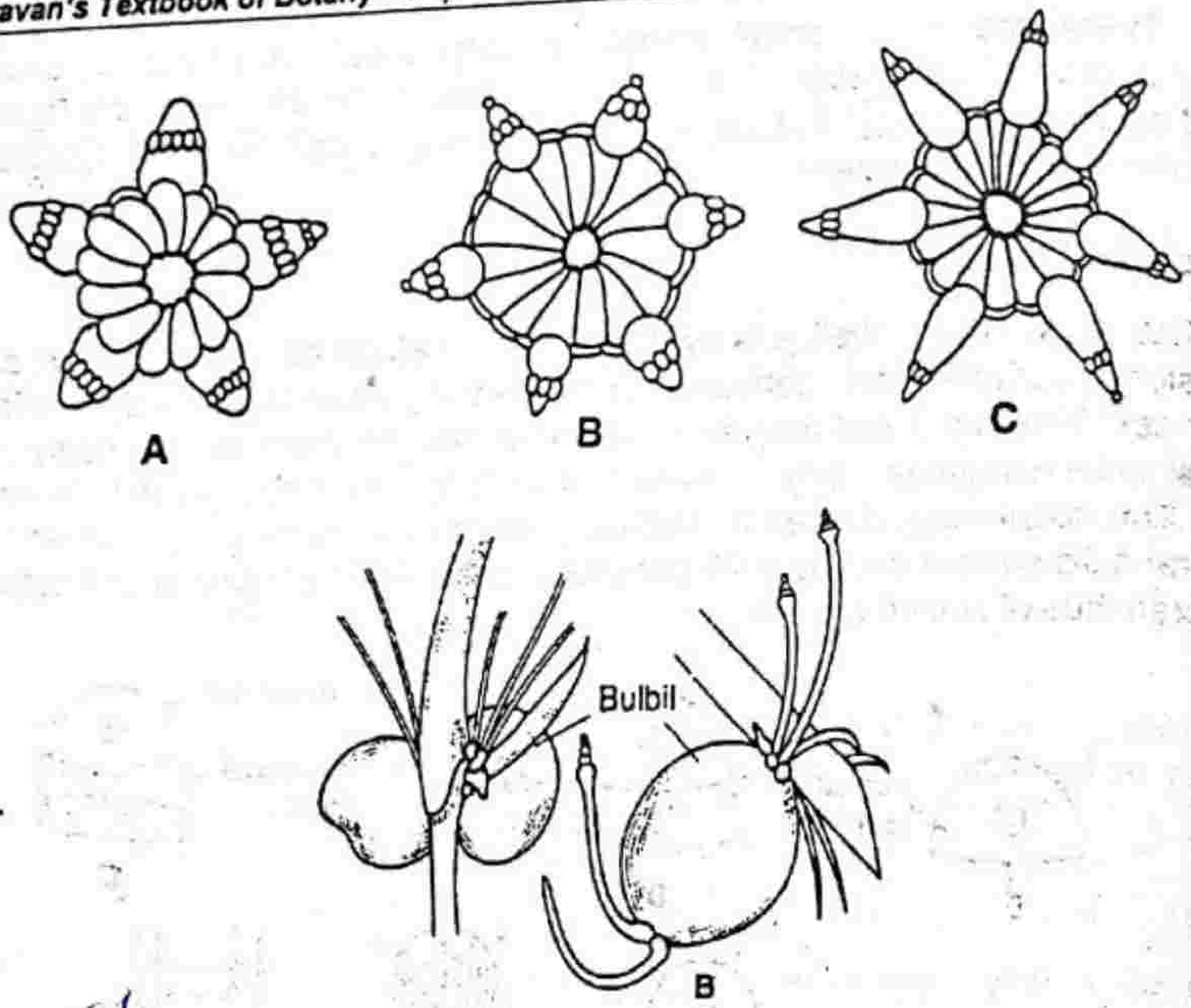


Fig. 4.17: Vegetative reproduction in chara.

(iii) 2ndary

iii. Secondary Protonema

In some cases protonema-like outgrowths arise from the node of primary protonema or from the basal cell of the primary rhizoid. These are called secondary protonema and develop into new plants like primary protonema.

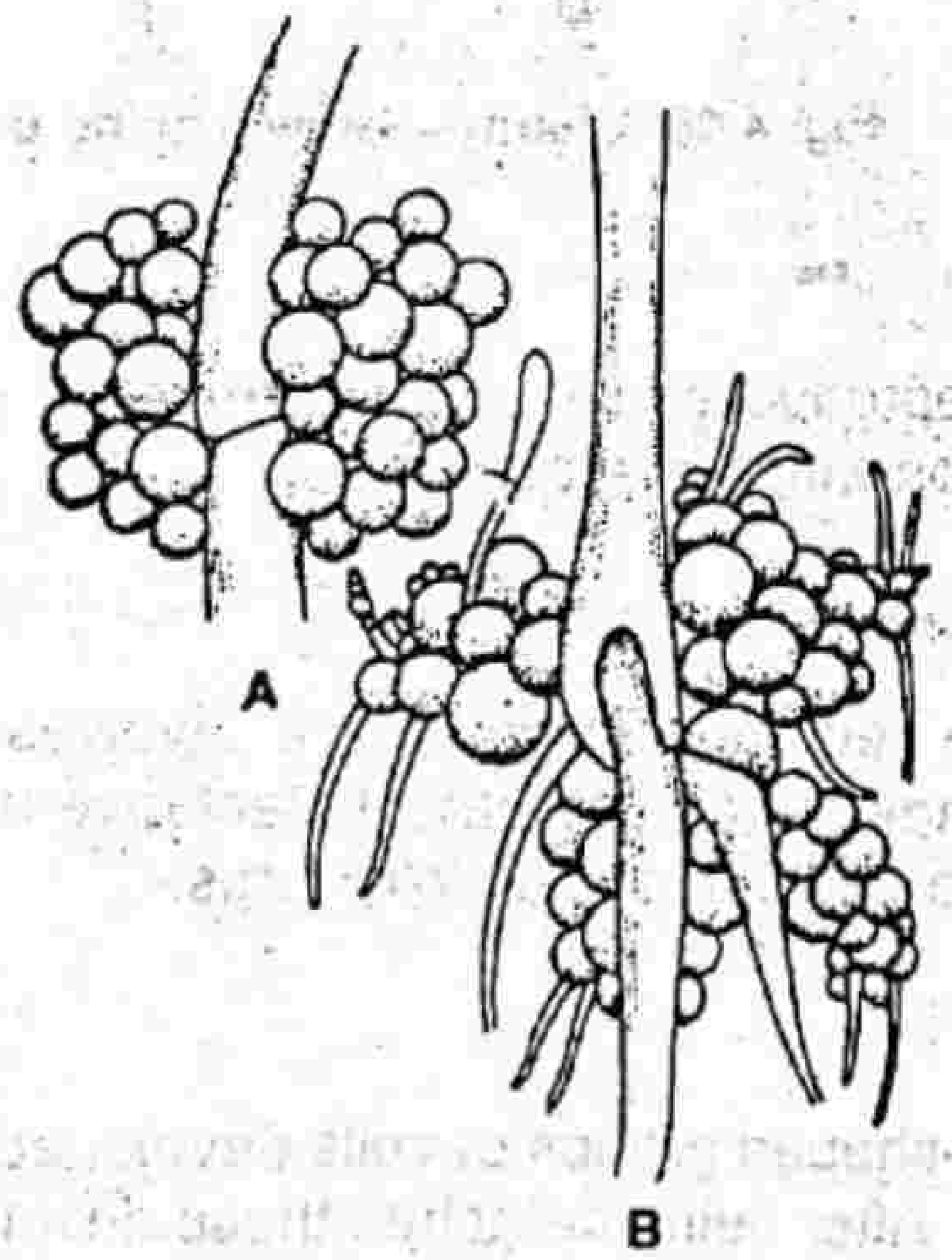


Fig. 4.18: Chara — Vegetative propagules.

Sexual Reproduction

The sexual reproduction is an advanced type of oogamous sexual reproduction. The gametes are produced in antheridia and oogonia that are enveloped in multicellular sheaths formed of cells derived from the cells present below the sex organs. These specialist complex structures containing the sex organs are called globule (male fructification) and nucule (female fructification). Some species are dioecious while the others are monoecious. The monoecious species are protandrous, i. e., the male sex organs develop first.

GLOBULE

The male fructification is called as globule. The mature globule is bright yellow in colour. It consists of following parts.

i.Pedicel cell

The globule is attached to the plant by a large cell called as pedicel cell. It extends within the cavity of the globule and join with the primary capitula.

ii. Shield cells

Each globule is in the form of ball like structure whose wall consists of large plate like eight cells called as shield cells. The outer wall of each shield cell has radial out growth therefore it appears as multicellular structure.

iii. Manubrium

On the inner side of shield cells in the center is attached an elongated cells called as manubrium.

iv. Primary capitula

The inner ends of manubrial cells are united to form eight isodimetric cells called as primary capitula.

v. Secondary capitula

Each primary capitula has one or two smaller cells towards the cavity of globule called as secondary capitula.

vi. Antheridial filament

Attached to the primary or secondary capitula are several branched uniseriate filament called as antheridial filament. Its contents are metamorphosed into a single antherozoid.

vii. Antherozoid

Each antherozoid is an elongated some what coiled structure. It bears two flagella.

Liberation of Antheridia

When the antherozoids are mature, the shield cells are separated from each other, exposing the antheridial filament. Antherozoids are than escape through a pore. The liberation of antherozoids may takes place in the morning and they may swim until the evening.

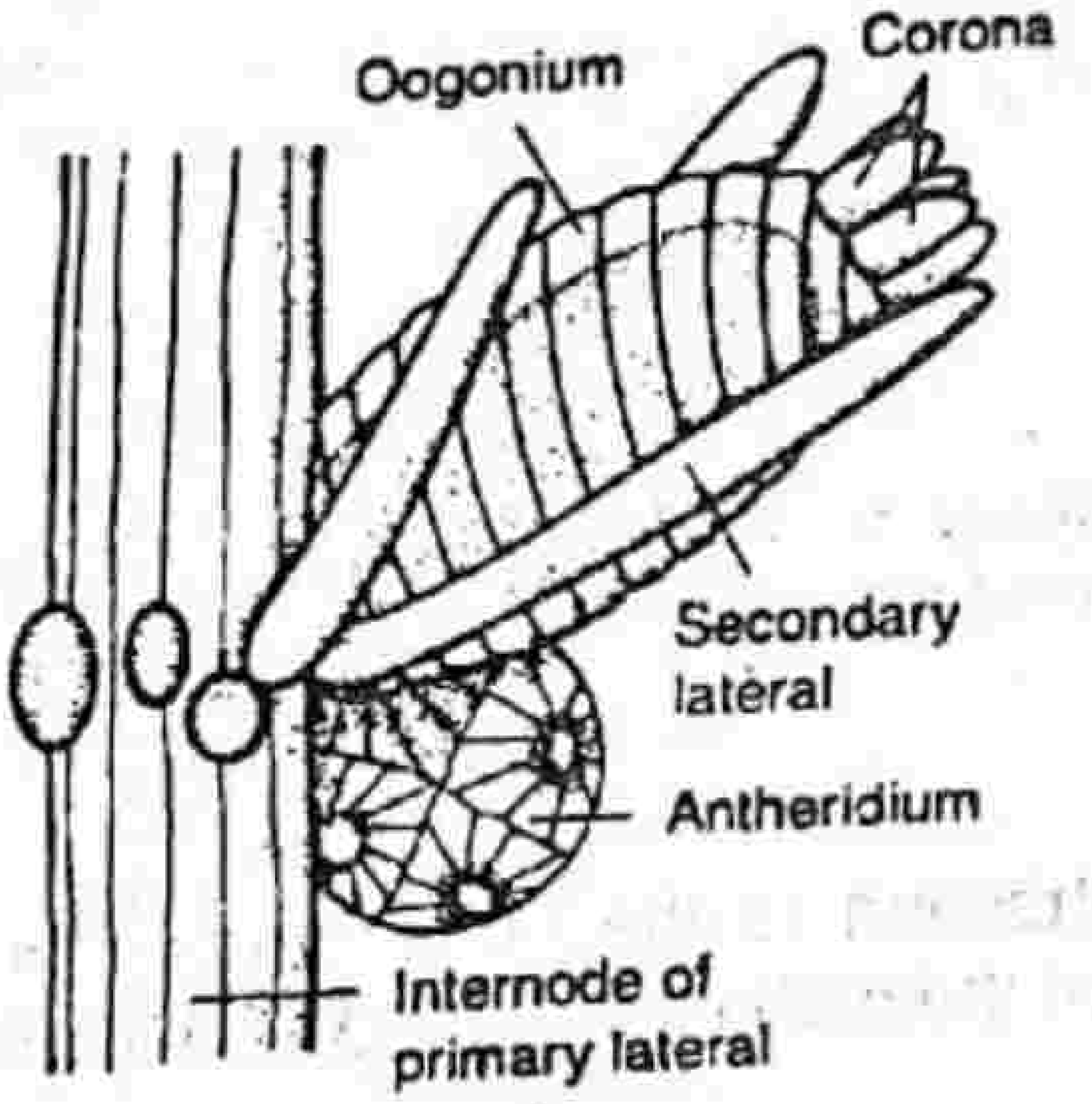


Fig. 4.19: Sex organs of chara

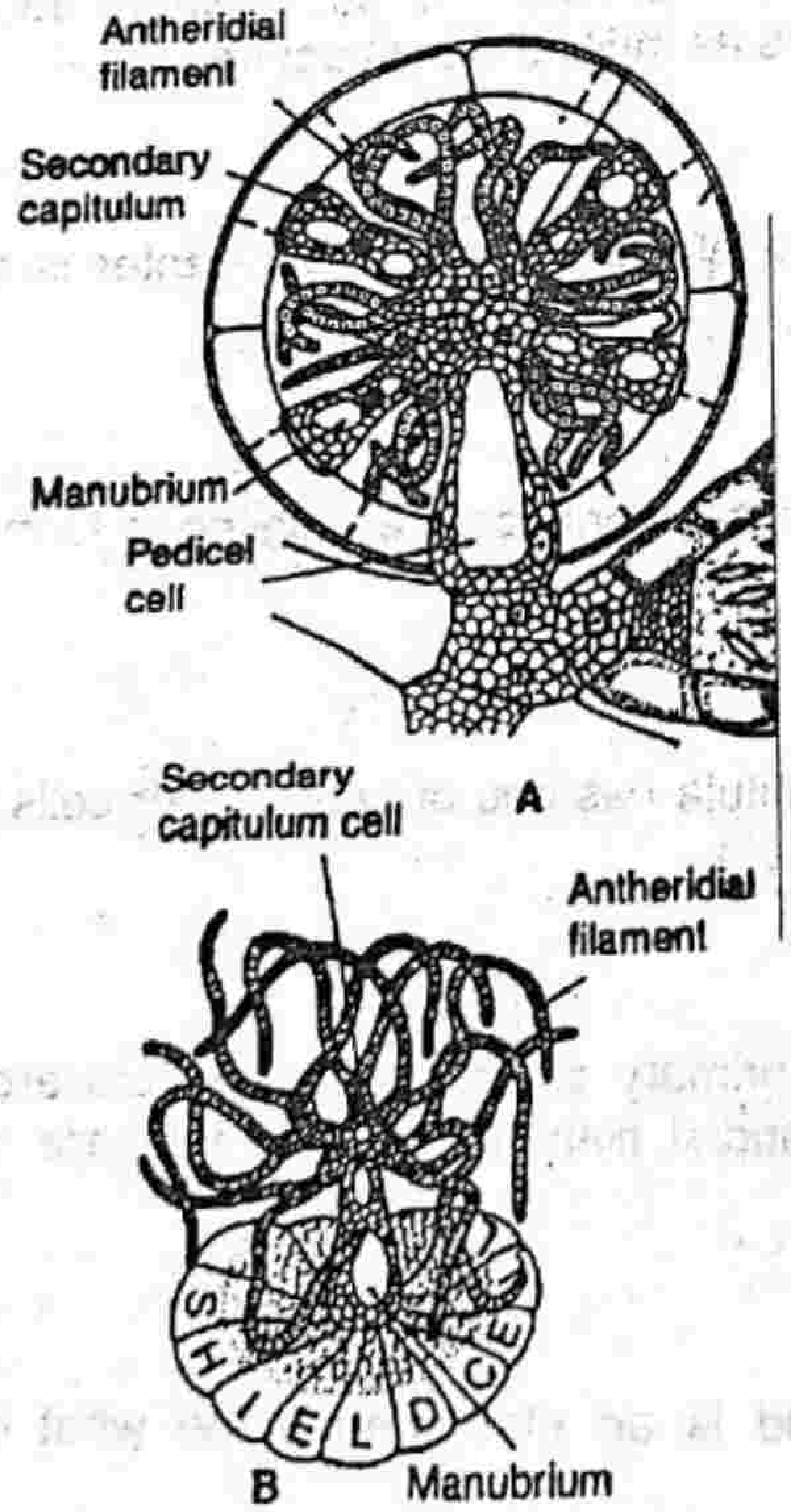


Fig. 4.20: L.S. of mature antheridium.

Development of Globule

The development of the globule starts from the adaxial peripheral cell of the lower node of a branch of limited growth. It divides by a periclinal division into an outer globule initial and an inner cell that undergoes another periclinal division. The lowermost cell act as internodal cell and the middle one forms the basal node of the antheridium. The basal nodal cell divides to produce five peripheral cells, the uppermost cell acting as nucule initial.

The globule initial divides transversely into a basal pedicel cell and a terminal antheridial mother cell. The pedicel cell does not divide further rather elongates and protrudes into the antheridial cavity. The antheridial mother cell becomes spherical and divides by two vertical divisions at right angles to each other to form a quadrat (only two are visible in a section). All these cells divide transversely to produce an octant of eight cells. Each of these eight cell divide periclinally into an outer and an inner cell. The cells of outer layer divides periclinally again and as a result three layers of cells are formed lying one above the other in the same radius. At this stage the antheridium consists of twenty four cells arranged in eight diagonal series of three cells each.

NUCULE

The female fructification is called as nucule. It consists of following parts

Pedicel cell

It is present at the base of the nucule on which are present central and stalk cell.

Oogonium

Upper to the stalk cell is a very much-enlarged structure called as oogonium. Its contents are transformed into a single large uninucleate egg.

Tube cells

The oogonium is covered by five elongated spirally twisted cells, called as tube cells.

Corona

At the top of the oogonium is a crown of small five cells called the corona.

Development of Nucule

The nucule initial divides twice transversely to produce a filament of three cells. The lowermost cell elongates and function as pedicel of the nucule. The middle cell divides by vertical divisions to form five sheath initials surrounding a central cell. The terminal cell functions as oogonium mother cell. It elongates and divide transversely into a lower small stalk cell and an upper oogonium. The oogonium enlarges and its contents metamorphose into a single egg.

The sheath initials elongate, grow upward, and divide transversely to form two tiers of five cells each. The cells of the upper tier function as corona cells and these form the corona of the nucule. The cells of the lower tier act as tube cells. The tube cells elongate and twist spirally in clockwise direction around the oogonium. The egg becomes filled with starch and oil, its nucleus migrates towards the lower side and a receptive spot develops at the top of it.

Fertilization

When the nucule is mature, the spirally twisted tube cells separated from each other just below the corona to form five small slits. Antherozoids swim through these slits and enter into the sheath of nucule. One of the antherozoid enters the egg and fertilization is completed.

The zygote secretes a thick wall and become oospore. The zygospore falls to the bottom of the pond and germinates after a period of rest of few weeks or more

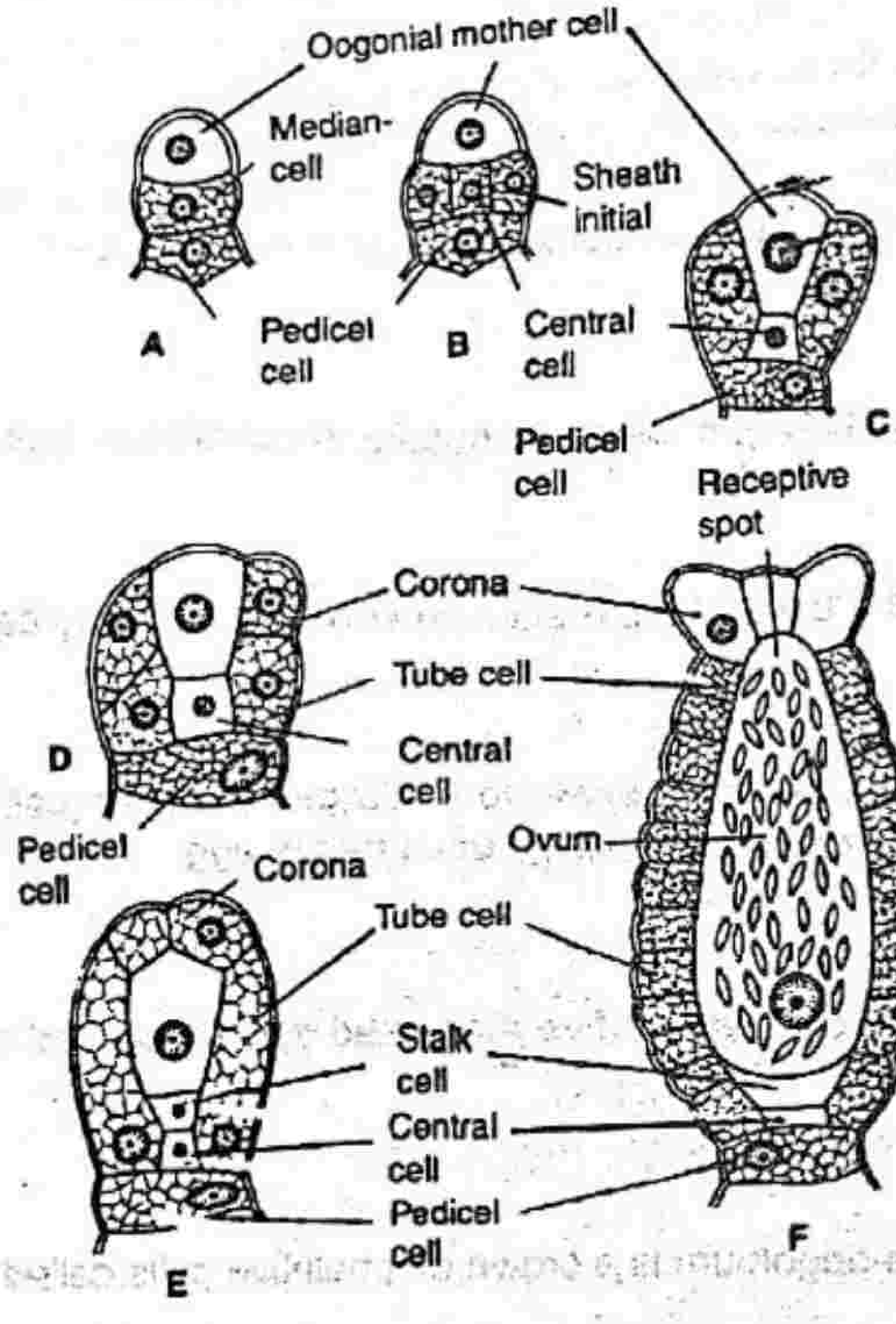


Fig. 4.21: Chara — Structure and development of nucule.

Structure and Germination of Oospore

The oospore germinates after a period of rest. Its nucleus divides by meiosis to produce four haploid nuclei. The oospore divided into two unequal cells by a wall. The upper cell is small and uninucleate and the lower cell is larger and contains three nuclei which disintegrate later on. The oospore wall burst open to expose the upper cell. It divides by an oblique longitudinal wall into a protonemal initial and a rhizoidal initial. The rhizoids develop from the rhizoidal initial and the protonemal initial develops into an erect primary prtonema which is differentiated into nodes and internodes later on. A new adult plant develops from the primary protonema.

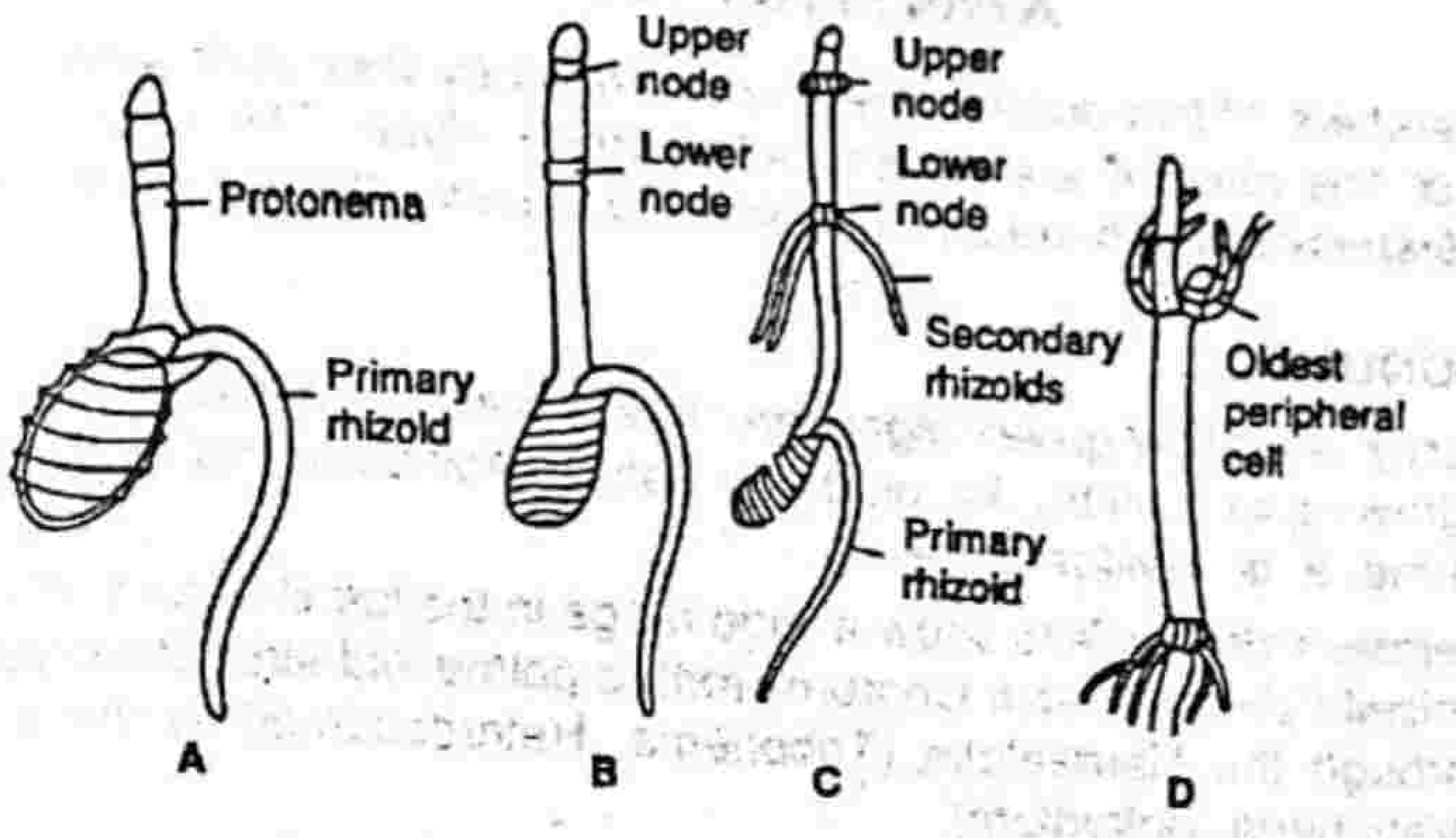


Fig. 4.22: Chara — Germination of oospore and development of a new plant.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are stone worts.
2. Enlist members of charophyta.
3. What are amylum stars.
4. What is protonema.
5. What is cyclic movement in chara.
6. What is globule.
7. What are the tube cells in chara.
8. Draw T.S. of globule of chara.
9. Describe vegetative reproduction in chara.
10. How chara thallus grow.

B. Long Questions

1. Describe vegetative structure of chara.
2. Write note on globule of chara.
3. Write note on nucule of chara.,
4. Describe development of sex organs of chara.
5. Describe life cycle of chara.

XANTHOPHYTA

The members of this division are characterized by their yellow-green colour. So, the members of this division are called yellow-green algae. The division includes 76 genera and 376 species which are included in a single class, the Xanthophyceae.

GENERAL ACCOUNT

1. A majority of yellow-green algae are freshwater but some of the species are aerial growing on tree trunks, on damp walls or soil on drying mud. A few species are marine, e. g., *Halosphaera*.
2. The members of the class show a wide range in thallus structure. The thalli range from unicell (Chloramoeba, Choromeson) to palmelloid state (Chlorosaccus), and also through the filamentous (Tribonema, Heterococcus) to the siphonaceous habit (Vaucheria, Botrydium).
3. The xanthophycean cell has a definite cell wall chiefly composed of pectic substances either pectose or pectic acid. In many genera the cell walls are in the form of two equal or unequal overlapping halves.
4. The cells in motile genera have two unequal flagella attached to the anterior end. One flagellum is tinsel type and the other whiplash type.
5. The pigments are located in discoid chromatophores and consists of chlorophyll-a, chlorophyll-e, beta-carotene and xanthophylls. Chlorophyll-b is absent. The dominant pigment is a xanthophyll, diadinoxanthin which provides the cells its characteristics yellow-green colour. The pyrenoids are absent.
6. The chief reserve foods are oil, lipid and leucosin (chrysolaminarin). Many genera have uninucleate cells while others have multinucleate ones.
7. The members of the class usually reproduce vegetatively and asexually, but in few genera sexual reproduction is also found.
8. The asexual reproduction may be by zoospores, aplanospores and akinetes.
9. The sexual reproduction is rare and is generally of isogamous type found among the siphonaceous genera like Vaucheria.

VAUCHERIA

Taxonomic Position

Division: Xanthophyta
Class: Xanthophyceae
Order: Heterosiphonales
Family: Vacheriaceae
Genus: *Vaucheria*

The genus was named in honour of Vaucher, a swiss phycologist.

Occurrence

It is found in temperate regions and comprises of about 45 species. Most of the species occur in fresh waters (in streams, springs and water falls) or found on damp soils and in ploughed fields forming green mats. A few species, e. g., *Vaucheria pilobolides*, are marine.

PLANT BODY

The thallus consists of sparingly branched cylindrical filament. The filament is non-septate multinucleated structure. Septa are produced only during the production of reproductive structure.

Hepteron

The plant is attached to the substratum by colorless branched, short rhizoids called as hepteron.

Cell wall

The cell wall is thin and consist s of cellulose and pectin material.

Vacuole

Tubular filament contains a large central vacuole filled with cell sap.

Chloroplast

The chloroplast is small discoid shaped structure with out pyrenoids.

Reserve food

Reserve food material is in the form of oil drops. Starch produced only if the plant is continuously illuminated with light.

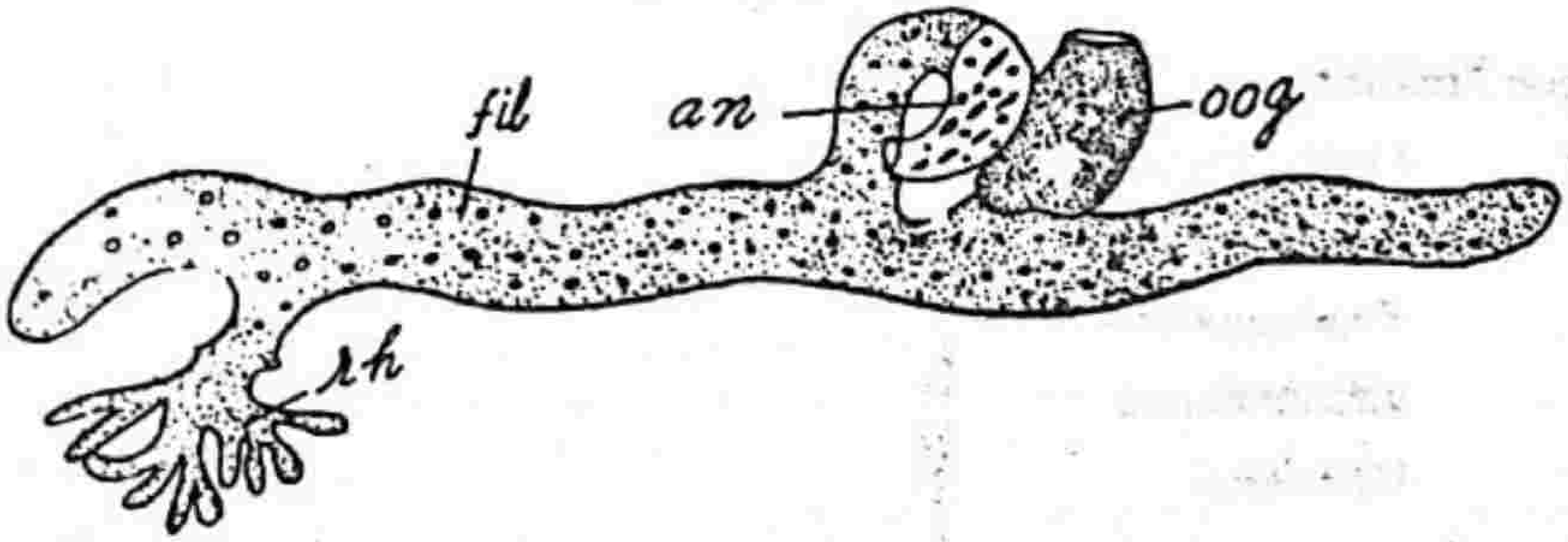


Fig. 4.23: A filament bearing Sex organ.

Reproduction

Vaucheria reproduces by vegetative, asexual and sexual methods of reproduction.

Vegetative Reproduction

The vegetative reproduction is by fragmentation. The filaments are broken accidently into fragments, each of which develops into a new plant. However, this mode of reproduction is not common.

Asexual Reproduction

In aquatic species the asexual reproduction takes place by multiflagellate zoospores, whereas in terrestrial species it is by aplanospores. The terrestrial species form zoospores when flooded with water.

Zoospores — Structure and Development

A single compound, multiflagellate zoospores is produced in a club-shaped zoosporangium which is cut off from the ends of erect aerial branches. The end of the filament becomes swollen and a large number of nuclei and chloroplasts aggregate there. This part is then cut off from the rest of the filament by formation of a septum. The central vacuole decreases in size and the nuclei arrange themselves at the periphery of the zoosporangium. The entire protoplast contracts and two slightly unequal flagella develop opposite each nucleus. This compound structure may be regarded as a group of biflagellate zoospores which have failed to separate. The center of the zoospore is occupied by a central vacuole.

The zoospore is liberated by the formation of a narrow pore in wall of the zoosporangium. After swarming for time, the zoospores settle down and undergo a period of rest. The flagella first become motionless and then disappear. The zoospore secretes a thick wall around it. It germinates by sending tubular outgrowths. One of these tubeact as rhizoidal branch.While, the other forms the yellowish-green filament.

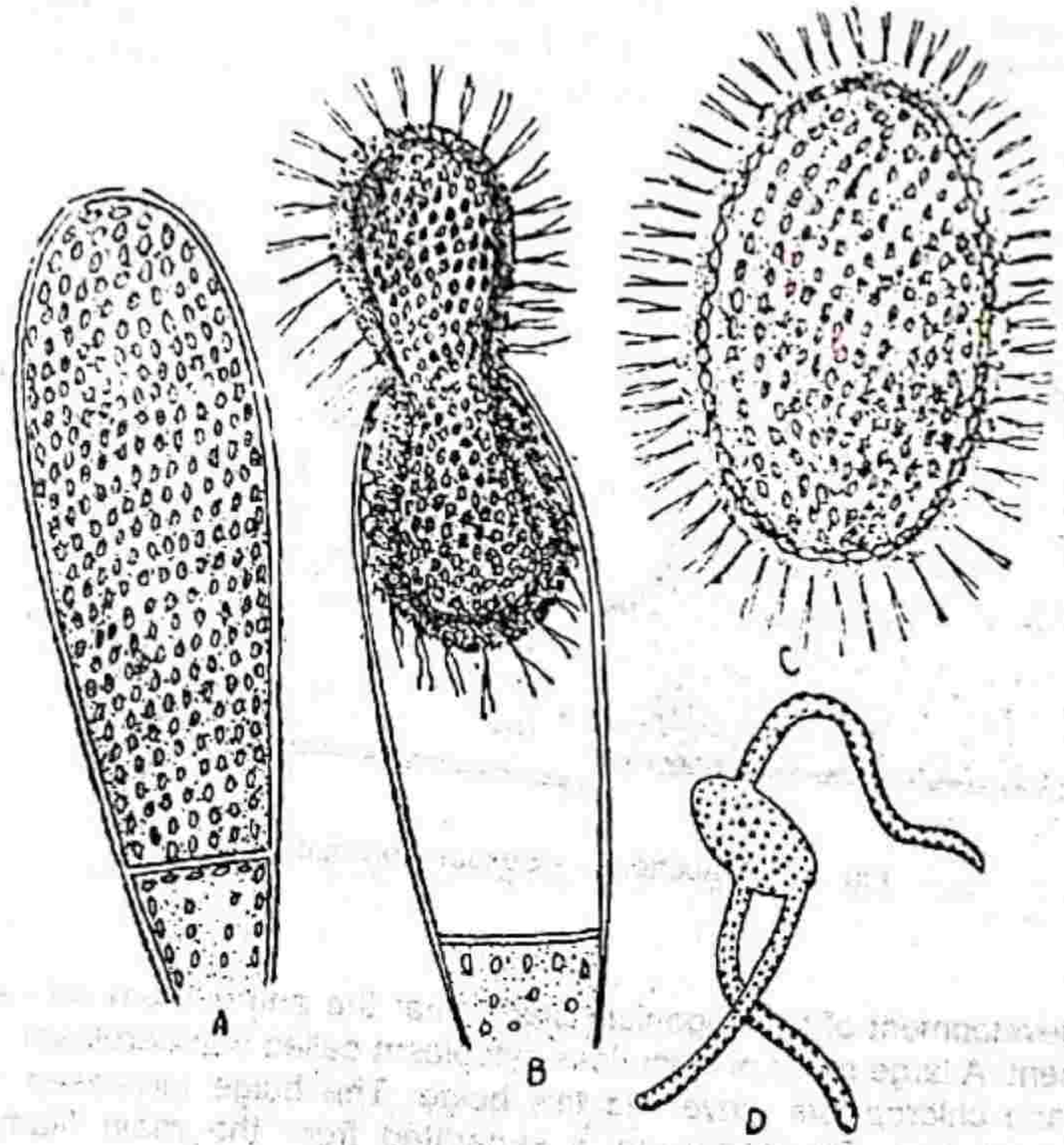


Fig. 4.24: Vaucheria — Asexual reproduction.

Aplanospores

The terrestrial species produce thin-walled aplanospores under dry conditions. These are formed in aplanosporangia produced at the ends of short lateral or terminal branches. The entire protoplast of the aplanosporangium is converted into a single rounded aplanospore. The aplanospore is liberated by a rupture in the wall of the aplanosporangium and develops into a new thallus.

Sexual Reproduction

The sexual reproduction is distinctly oogamous and the different species may either be monoecious or dioecious. The sex organs are antheridia and oogonia. The oogonia are of larger size, may be sessile or stalked, and produced on main filament or on special reproductive branches.

Antheridium

A mature antheridium is usually stalked, cylindrical, tubular, often hook-shaped structure that develops before the start of development of oogonium in most of species. It develops close to oogonium. The branch bearing the antheridium becomes densely packed with nuclei and a few chloroplasts, therefore the antheridium is often colourless. Later on this branch is cut off from rest of the thallus by a transverse septum. The contents of the antheridium divides into uninucleate fragments which metamorphose into a biflagellate, pear-shaped antherozoids. The flagella are unequal in size, laterally inserted and pointed in opposite directions. The smaller one is of tinsel and the larger one is of whiplash type. The antherozoids are liberated through apical pores formed in the antheridium and reach oogonium.

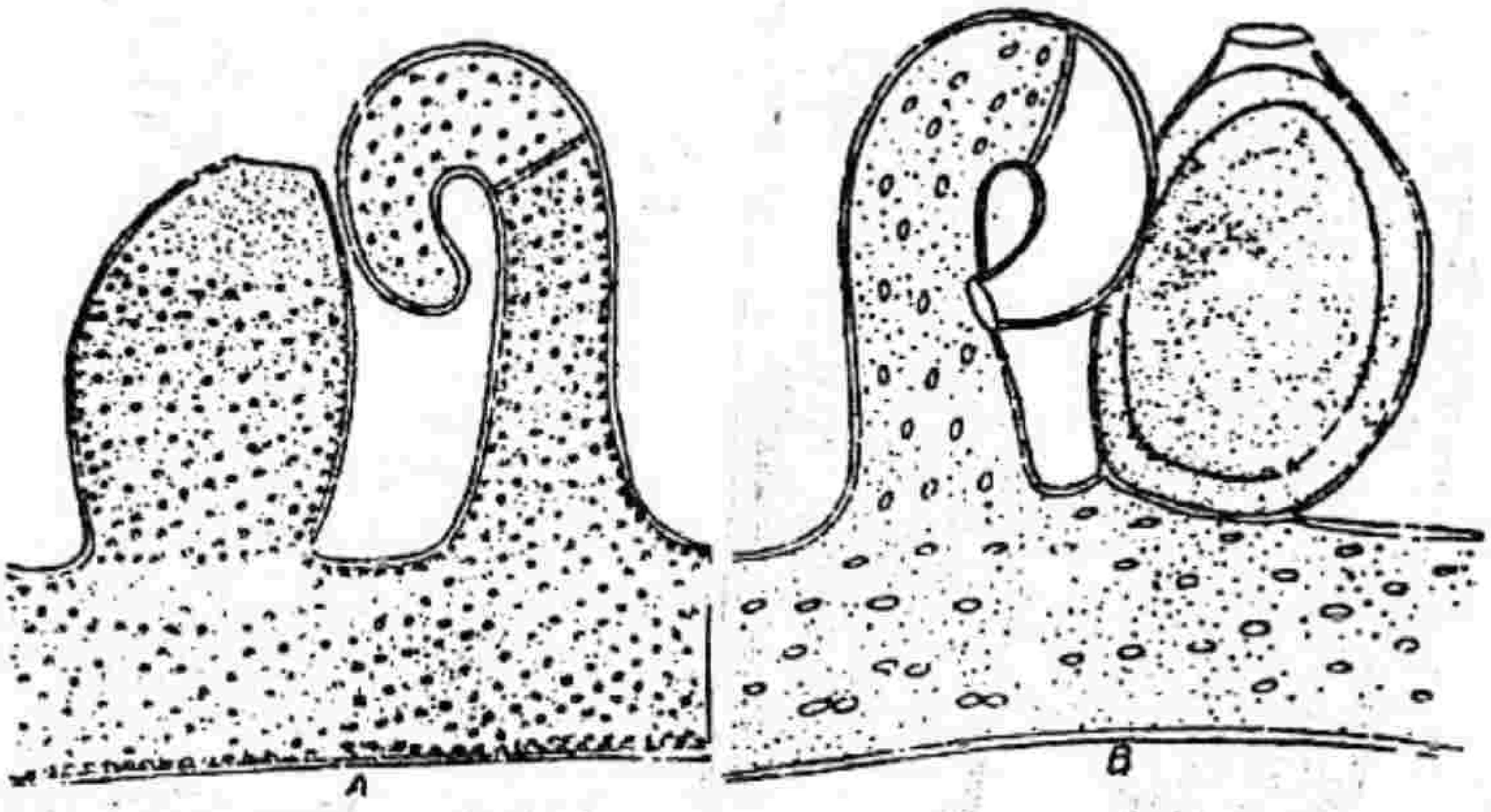


Fig. 4.25: Vaucheria — Sexual reproduction.

Oogonium

The development of the oogonium starts near the antheridium with a bulging in the main filament. A large mass of colourless cytoplasm called wanderplasm, followed by many nuclei and chloroplasts move into this bulge. The bulge increases in size and becomes an oogonium. The oogonium is separated from the main filament by the formation of a transverse septum. The entire protoplast metamorphose into a single, large, spherical, uninucleate ovum or oosphere. At one side of the oogonium a beak called the receptive spot develops. The apex of this beak gelatinize and form apical pore through which the antherozoids can enter the oogonium.

Fertilization

The sex organs mature almost at the same time. One of the liberated antherozoids enters the oogonium through the pore formed at the receptive spot and lie near the female nucleus. The male nucleus increases in size upto the size of the female nucleus and then fuses with it to form a zygote. The zygote secretes a thick wall around it to become an oospore.

Germination of Oospore

The oospore undergoes a period of rest for some months before germination. On germination it produces a new filament directly. The meiosis occurs at the time of germination of the oospore, indicating that the adult plant is a haploid.

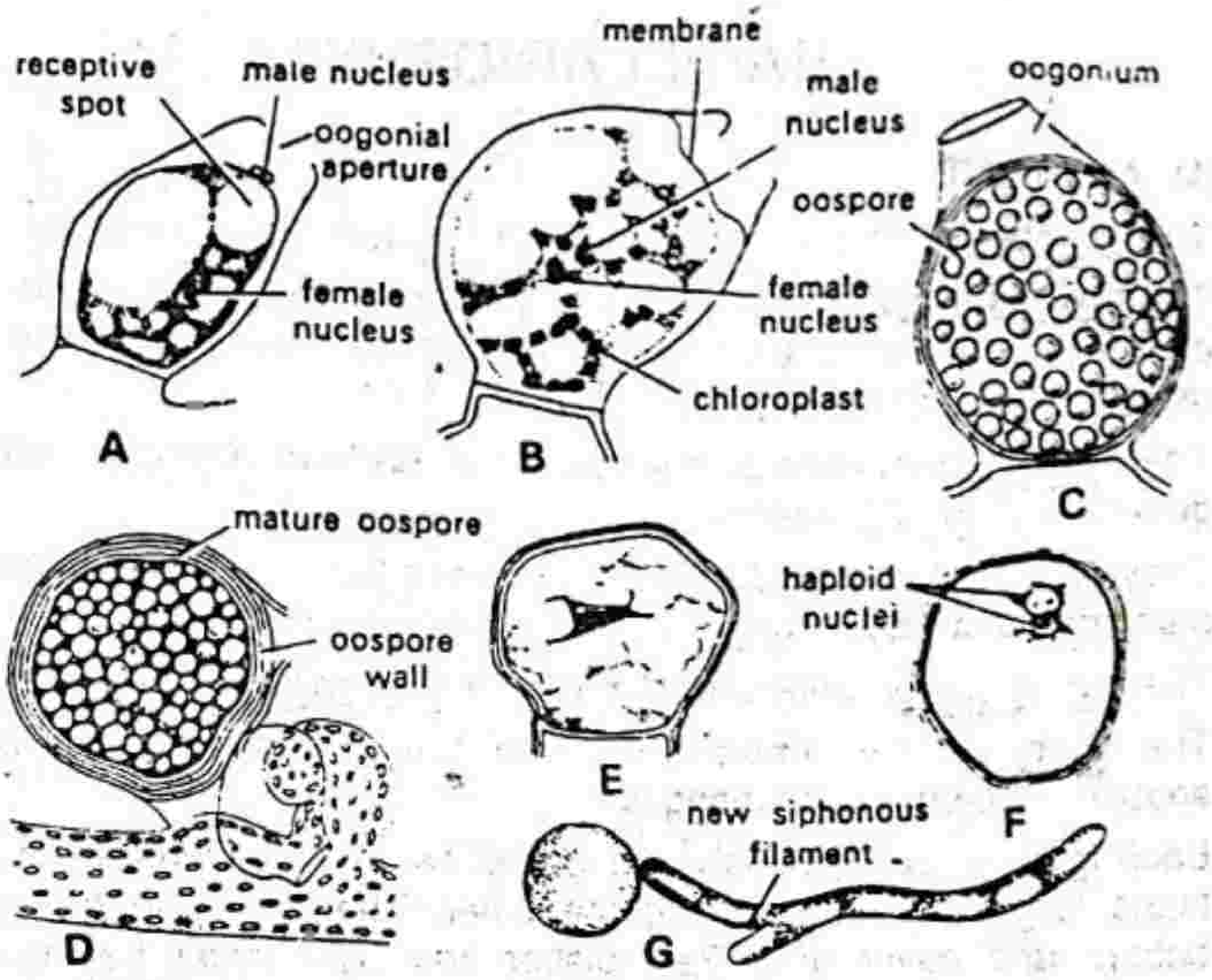


Fig. 4.26: Vaucheria — Fertilization, oospores formation and germination of oospore.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Give pigmentation in xanthophyceae.
2. What is heptron.
3. Which type of reserve food is found in Vaucheria.
4. What is the structure of Vaucheria zoospore.
5. What is the importance of oospore.
6. What is structure of antheridium.
7. What is siphonacious plant body.
8. Define coenocytic plant body.

B. Long Questions

1. Describe vegetative structure of vaucheria..
2. Write note on asexual reproduction in vaucheria.
3. Write note on sexual reproduction in vaucheria.
4. Describe development of sex organs of vaucheria.
5. Describe life of vaucheria.

*f

BACILLARIOPHYTA

200 - 1600

GENERAL ACCOUNT

1. The members of this division are commonly termed as diatoms.
2. The abundance of diatoms in early geological periods is confirmed by presence of large deposits of their siliceous frustules. These deposits are termed as diatomaceious earth.
3. The division comprises of a single class: Bacillariophyceae including about 200 genera and 16,000 species.
4. They are found in abundant as unicells or colonial forms in marine or freshwater planktons and also as epiphytes on other algae and higher plants.
5. The thallus colour ranges from olive-green to brown in colour.
6. The shape of the genera vary from oval, rounded, elongated, conical, rod-shaped, disc-shaped to triangular.
7. Each frustule (cell wall) is composed of two overlapping halves, the valves, one being larger and overlapping the other. (Therefore, the frustule appears like bottom and cover of a Petri dishor box.) The larger half is called epitheca (theke=case) and the smaller is known as hypotheca.
8. The cell wall is impregnated with silica which is deposited at the surface of the cell from the silicic acid present in the environment surrounding the cell.
9. The reserve food is oil or chrysolaminarin.
10. The nucleus is suspend in the center of the cell with the help of cytoplasmic bridges. Other cellular organelle such as mitochondria, Golgi bodies and endoplasmic reticulum are also present. a-sexual spores
11. The diatoms reproduce by vegetative and sexual reproduction.
12. The most common method of vegetative reproduction in diatoms is simple by cell division.
13. The sexual reproduction in diatoms is either isogamous, anisogamous or oogamous. In all these types the gametes fuse to form zygote characteristics of diatoms. It is called auxospore (Gr. auxein=increase) since it is capable of remarkable increase in size after its formation.

Types of Diatoms

The diatoms are divided into two types on the basis of symmetry, sexual reproduction and locomotion:

i. Pennate Diatoms: These diatoms exhibit bilateral symmetry, amoeboid isogmaous sexual reproduction and gliding movements, e. g., *Pinnularia*.

Boat shape

ii. Centric Diatoms: Theses diatoms exhibit radial symmetry, anisogamous or oogamous sexual reproduction and lack of movement, e.g., *Melosira*.

گول round

[illegible]

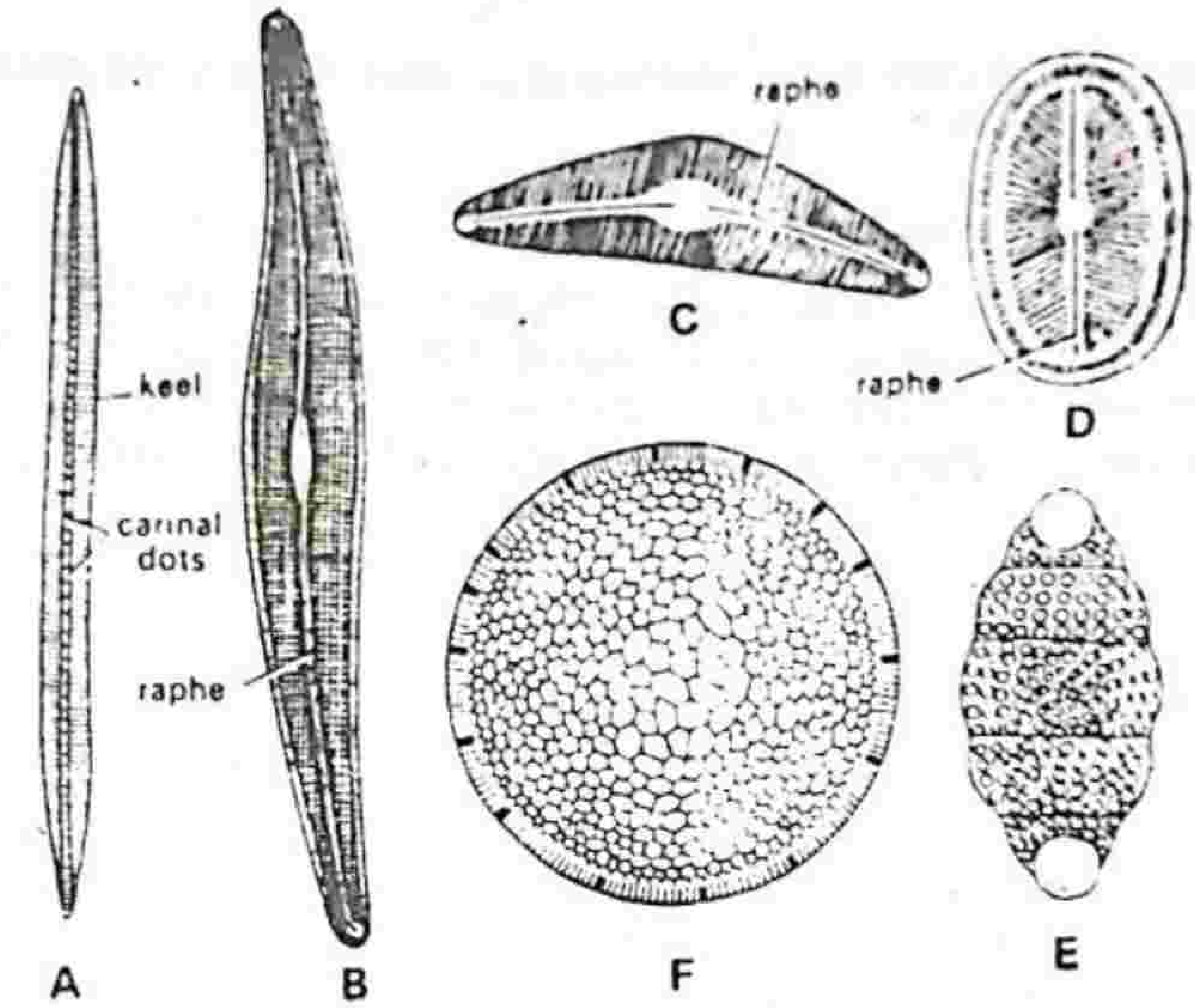


Fig. 4.27: A-D. Pennate diatoms; E-F. Centric diatoms

ECONOMIC IMPORTANCE

The diatoms are important economically as followings:

i. Role as Primary Producers

The diatoms are major constituents of planktic life, therefore play an important role as primary producers in the food chain alongwith other algae.

ii. Source of Food

The diatoms constitute an important source of food for aquatic animals including fish and whale. The chief reserve food in diatoms is oil. These oils are rich source of vitamin A and D.

iii. Diatomaceous Earth

The diatoms have lived for many ages. The indestructible siliceous frustules of diatoms have formed rock-like deposits called diatomaceous earth. It is mined to obtain a whitish powder, the diatomite, which is used variously:

a. It is used as filters in sugar, brewing and medicine industries because of its high absorbent nature.

b. It is used as absorbent for nitroglycerine in the manufacture of dynamite.

c. It is used as insulation material for pipes and furnaces and manufacture of heat-proof bricks, due to fire-proof property.

d. It is used in manufacture of water-glass because of its siliceous contents.

e. The diatomite is sprinkled on the walls of coal mines to reduce the danger of secondary explosions.

f. The diatomite is used in manufacture of polishes for cars and metals because of its abrasive nature.

iv. Source of Petroleum Products

The diatom bodies contain about 11% oil by volume, therefore it is suggested that these may the source of oil. The oil contents in their bodies condensed and stored in certain pockets and then fossilized into petroleum products. The frustules have been found to be valuable indictors for presence of oil and bitumen at a place.

PINNULARIA

①

(1st)

Taxanomic Position

Division: Bacillariophyta
Class: Bacillariophyceae
Order: Pennales
Family: *Naviculoideae*
Genus: *Pinnularia*

Habitat

Pinnularia is very common in fresh water ponds, ditches, on the surface of mud in the drying ponds and on the moist soils.

Structure

The plant consists of single cell, which is elongated or elliptical in outline. The cell is 7-8 times as longer as broad. Under the microscope it gave following demarcations

Cell wall

The outer covering of the cell is called as cell wall. The cell wall is made up of pectic material which is impregnated with silica. So the cell became very hard.

Valves

The frustules consist of two overlapping halves called the valves. The flat view is called as valve view while the band view is called as girdle view. The two valves instead of overlapping each other directly, are attached to each other by incurved edges of the valves called girdles or connecting bands. When viewed either from above or below, the valve view, the cell usually have parallel sides and rounded polar portions and when observed in lateral aspect, the girdle view, the cell appears rectangular.

Raphe

It is characteristic marking and present on the valve view. Each valve of Pinnularia is marked by two series of prominent rib-like lines, the costae which extend from margins to the central region of the wall. The central region of the wall is traversed by a cleft or groove called the raphe. The raphe is not straight but is sigmoid in shaped.

Central nodule

The raphe is not continues but it is interrupted in the middle by a circular thickening called the central nodule.

Polar nodule

The thickening is also present on the outer end of raphe and is called as polar nodule.

Cytoplasm

The cytoplasm is arranged in a parietal layer, inside the cell wall and enclose a large central vacuole.

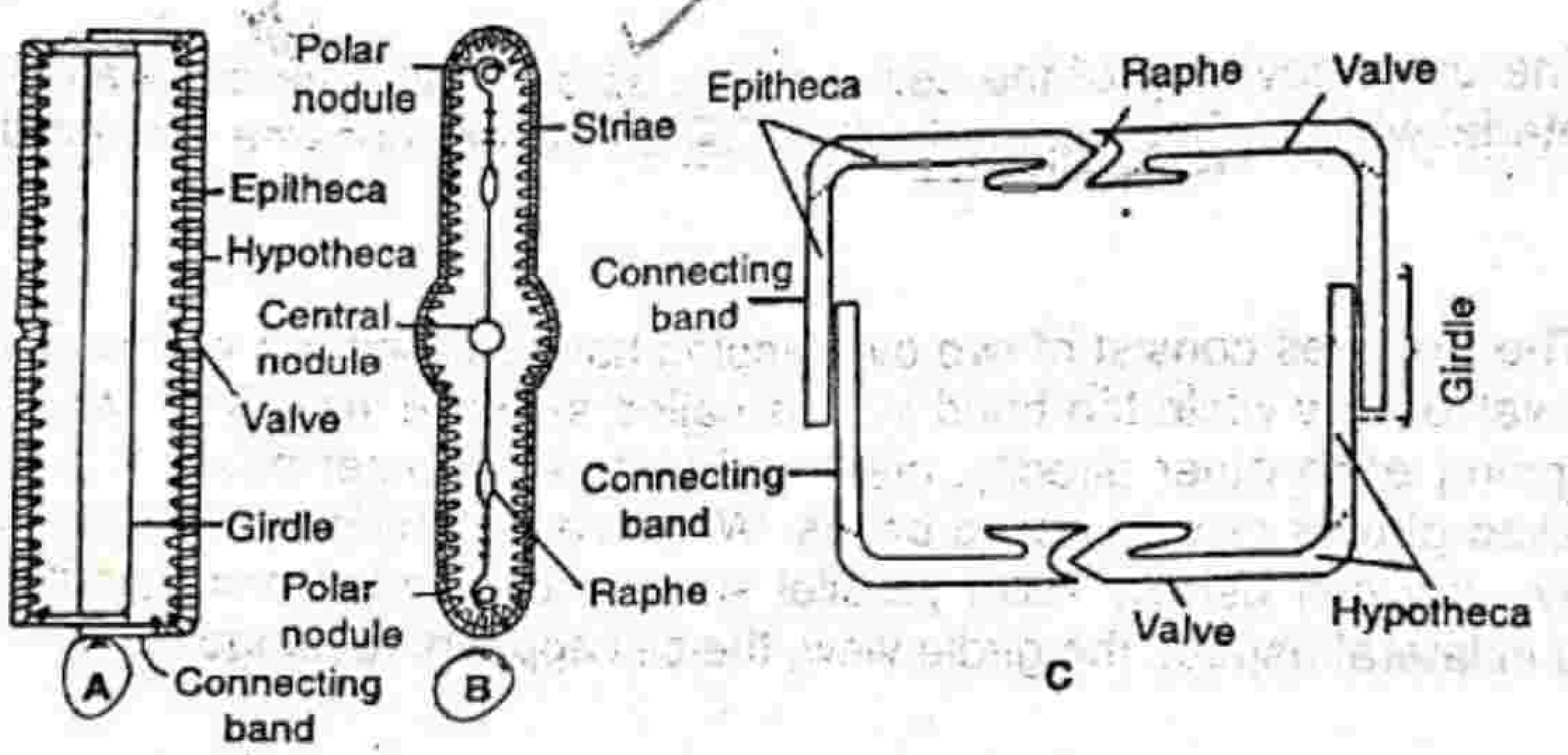
Nucleus

The single nucleus is suspended in the center of the vacuole by a cytoplasmic bridge.

Chloroplast

There are two laminate chloroplast embedded in the cytoplasm. These contain a pigment called as diatomin in addition to the normal photosynthetic pigments. One or two pyrenoids are present in each chloroplast. The chief food reserve is in the form of oil drops.

The most conspicuous of cytoplasmic structures are the brownish plastids which contain chlorophyll-a and -c, beta-carotenes and a number of xanthophylls including the fucoxanthin which masks the chloroplasts and is responsible for the characteristics colour of the plant thallus. The plastids are few in number and are massive. The excess food is stored in the form of oil or chrysolaminarin. Electron microscopy has revealed the presence of mitochondria and Golgi bodies.



Ⓑ Ⓐ

Fig. 4.28: Pinnularia — Frustule in valve and girdle view.

Locomotion

The plant exhibit characteristics gliding movements which are brought about by circulation of streaming cytoplasm within the raphe and by the secretion of the mucilage through the raphe and its hydration.

Reproduction

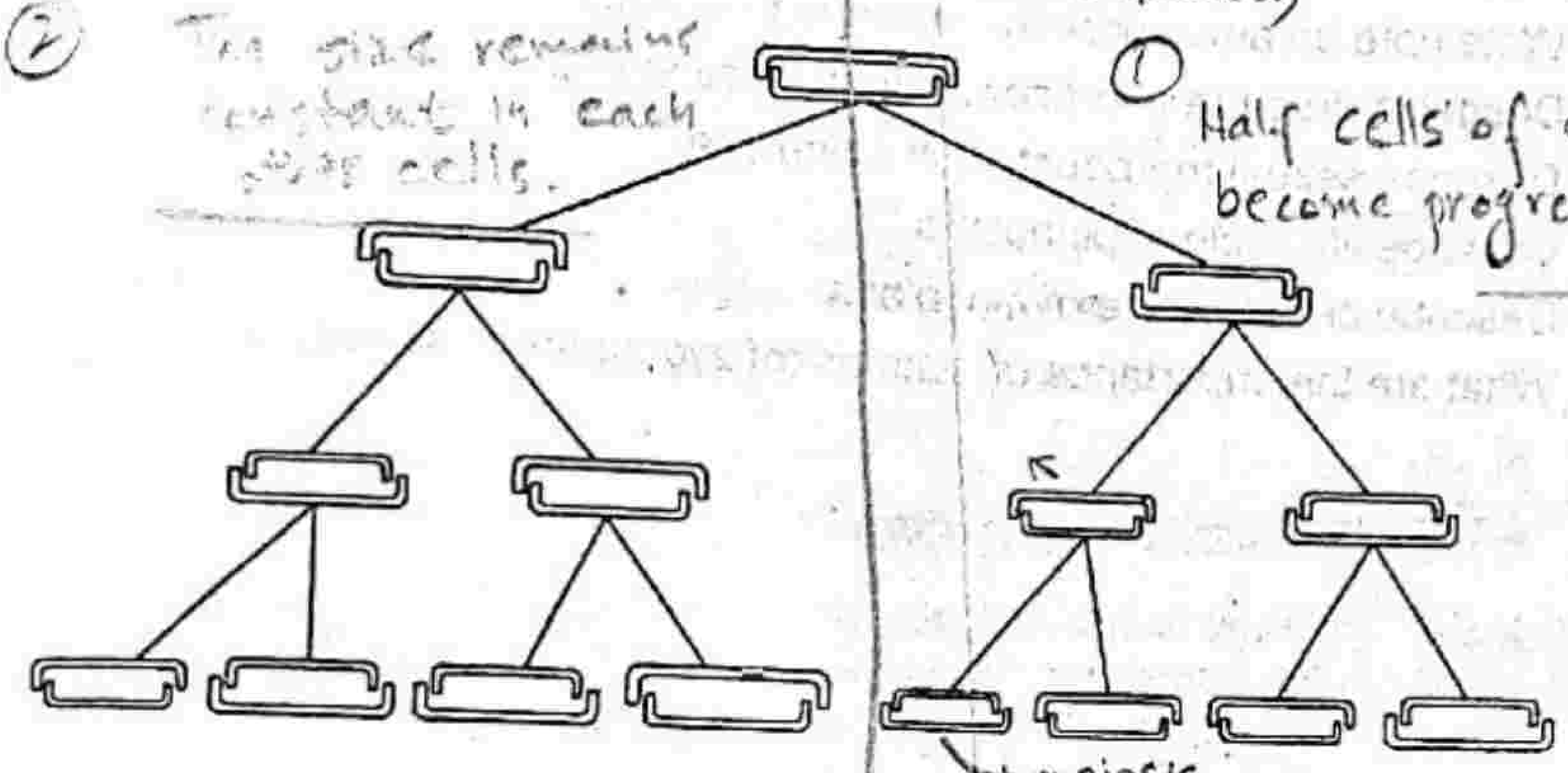
The plant reproduces (vegetatively by cell division) and (sexually by production of auxospores)

both

Vegetative Reproduction — Cell Division

① This is the most common method of reproduction that results in the formation of two daughter cells of slightly different size. The first indication of division is expansion of the protoplast that causes a slight separation of overlapping epitheca and hypotheca. → تخيل This is followed by mitotic division of the nucleus in a plane perpendicular to the valves. The nuclear division is accompanied with duplication of cell organelle especially those of chromatophores and pyrenoids. Later the protoplast divides in a plane parallel to the valves. One daughter protoplast lies within the epitheca and the other within the hypotheca. Each daughter protoplast secretes a new half next to its girdle and free face. At this stage the parent connecting bands separate and each cell becomes an independent cell. ([illegible] ← (خالي جلي)

② The two frustules of each parent cell act as epitheca of the two daughter cells. Therefore, newly formed half wall is always hypotheca of daughter frustule. The utilization of two old half walls as epithecae for the daughter cells results in one cell of the same size as the parent cell and the other being slightly smaller than the original parent cell. This progressive diminution in size result in a population with smaller cells, however this reduction in size does not continue indefinitely. It is checked by formation of auxospores which give rise to vegetative cells of maximum size for the species.

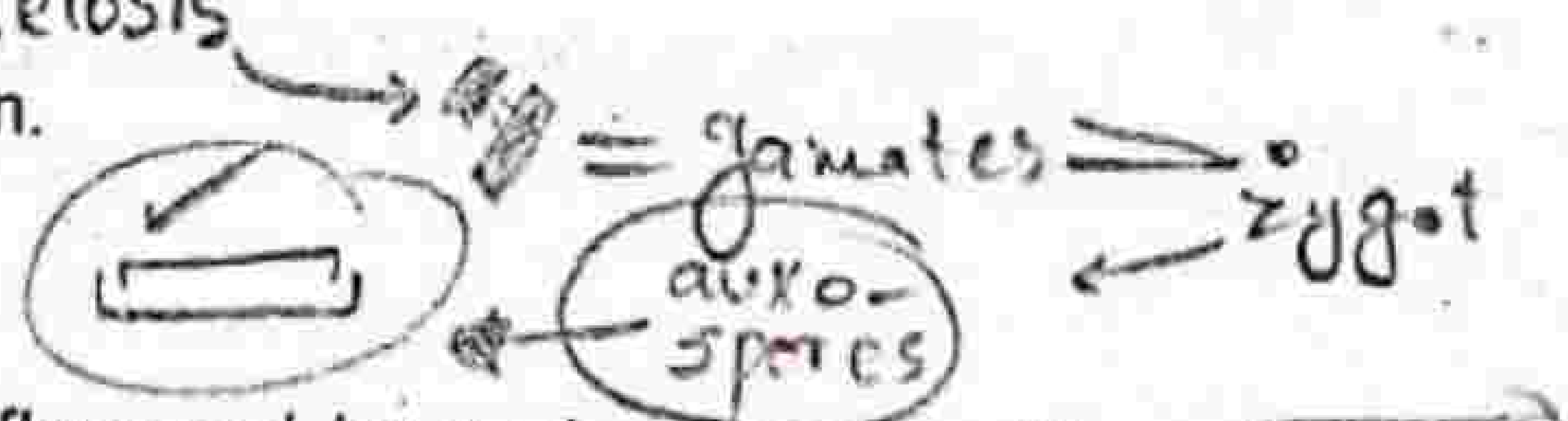


② The size remains constant in each [illegible] cells.

① Half cells of each generation become progressively smaller.

→ meiosis

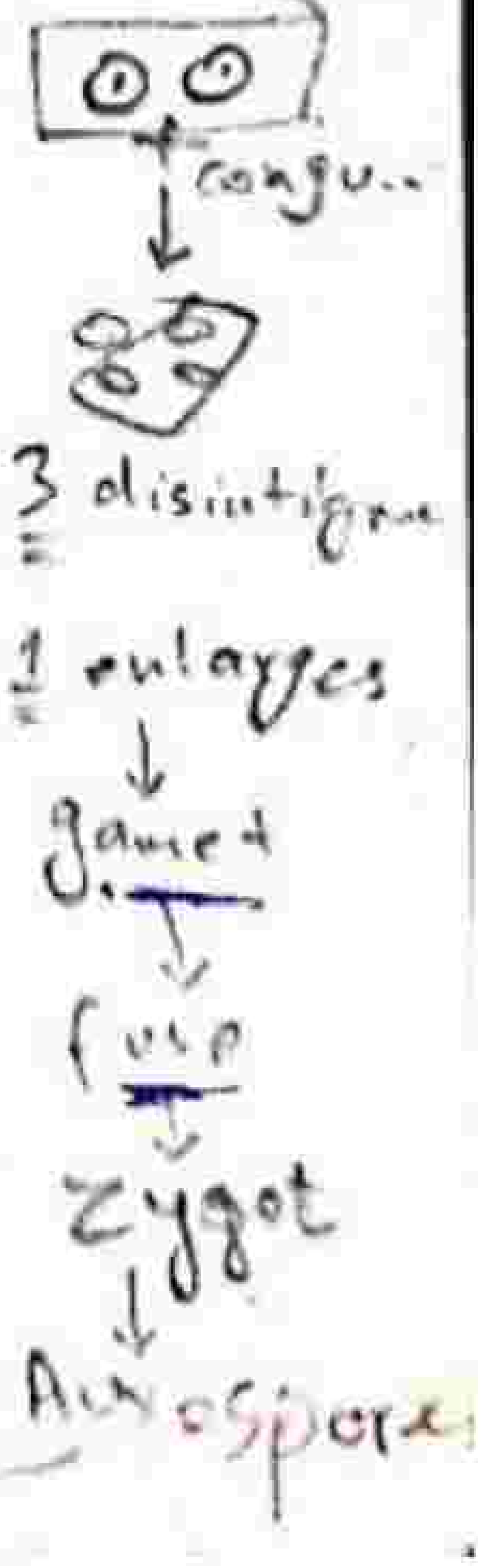
Fig. 4.29: Diatom Cell Division.



Sexual Reproduction

The sexual reproduction is isogamous and is influenced by various factors like temperature, light conditions and nutrition. The Pinnularia species are monoecious. The zygote grows into a specialized spore, the auxospore which enlarge to the size of the parent cell and restores the parental size of the vegetative cell.

In Pinnularia two cells from common parent or different parents become enveloped in a common mucilaginous sheath (conjugation). The nuclei of both cells divide by meiosis to produce four nuclei, out of which three disintegrate and the surviving one enlarges. The protoplast metamorphoses into a gamete. The gametes are liberated from the parent frustules and fuse to form a zygote which enlarges to become an auxospore. The auxospore secretes new valves to become an adult.



Adult

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What is the importance of auxospore.
2. What is the taxonomic position of Pinnularia.
3. What is pennate diatoms.
4. What is the importance of cell division in pinnularia.
5. What is the structure of pinnularia.
6. How auxospore if formed.
7. What is raphe. Give its importance.
8. Describe asexual reproduction in pinnularia.
9. What is chemical composition of cell wall.
10. What is diatomecious earth.

B. Long Questions

1. Write note on auxospore formation in pinnularia.
2. Describe structure and asexual reproduction of pinnularia.
3. Describe sexual reproduction in pinnularia.
4. Describe life cycle of pinnularia.
5. Describe cell structure of pinnularia.
6. What are the importance of diatoms. of zygospore in spirogyra.

+✓ Find

PHAEOPHYTA

I.O

GENERAL ACCOUNT

chlorophyll present (as?) (instead of green.)

1. The members of this division are commonly called brown algae because of dominant carotene and fucoxanthin.
2. The brown algae are widespread and with few exceptions all are marine. They grow attached to the rocks, shells, or coarser algae such as the kelps. In general the brown algae flourish in colder ocean waters and on rocky coasts, where they grow attached in intertidal or littoral zone e. g., the members of Fucaceae and Laminariales.
3. They range from minute discs to thalli 100 meters or more in length.
4. The filamentous forms (*Ectocarpus*) are uniaxial, however in parenchymatous species (Fucus) the plant body may be differentiated into a holdfast, through which it is attached to the substratum; a long or short stipe; and expanded leaf-like fronds that act as photosynthetic and reproductive organs.
5. The growth of the thallus in primitive brown algae is by an intercalary meristem at the base of a hair or filament. This type of growth is called trichothallic growth, e. g., in Ectocarpus.
6. The cell is surrounded by distinct cell wall composed of an inner cellulose layer and an outer pectin layer. The outer layer becomes slimy or gummy due to presence of pectic compounds. The most important constituent of the cell wall is alginic acid found in the outer layer of the cell wall. It forms a colloidal substance algin which is important economically.
7. The reserve food is mannitol and laminarin starch.
8. The brown algae reproduce by vegetative, asexual and sexual means of reproduction.
9. The asexual reproduction is by pyriform or spindle-shaped motile zoospores with two unequal flagella. The zoospores are produced in either in one-celled unilocular sporangia or in many-celled plurilocular sporangia.
10. The sexual reproduction ranges from isogamy to oogamy through anisogamy.
11. Except for in Eucales all other members show either isomorphic or heteromorphic type of alternation of generations.

ECTOCARPUS

1st

(2)

Taxonomic Position

Division:	Phaeophyta
Class:	Isogeneratae
Order:	Ectocarpales
Family:	*Ectocarpaceae*
Genus:	*Ectocarpus*

Occurrence

Ectocarpus (ecto=external + carpus=fruit) is a marine brown alga abundantly found throughout the world in cold waters. A few species have been reported to occur in fresh waters. The plant grows attached to rocks and stones along coasts both in the littoral and sub-littoral zones. Some species are epiphytes on other algae especially the members of Fucales and Laminariales.

PLANT BODY

The thallus consists of sparsely or profusely branched uniseriate filaments and exhibits heterotrichous habit. There are two types of filaments, the prostrate and erect filament.

Prostate Filament

The prostrate system comprises of creeping, septate, irregularly branched filaments that are attached to the substratum with the help of rhizoids. In epiphytic species this system occasionally penetrates the host. In free floating species the prostrate system is poorly developed.

Erect Filament

The projecting system arises from the prostrate system and consists of well branched filaments. The branching is lateral and each branch arises beneath the septa. The main axis and the branches of the projecting system are uniseriate (cells joined end to end in a single series). The branches terminate into an acute point forming a hair. In some species the older portions of main axis are ensheathed (corticated) by a layer of descending rhizoidal branches.

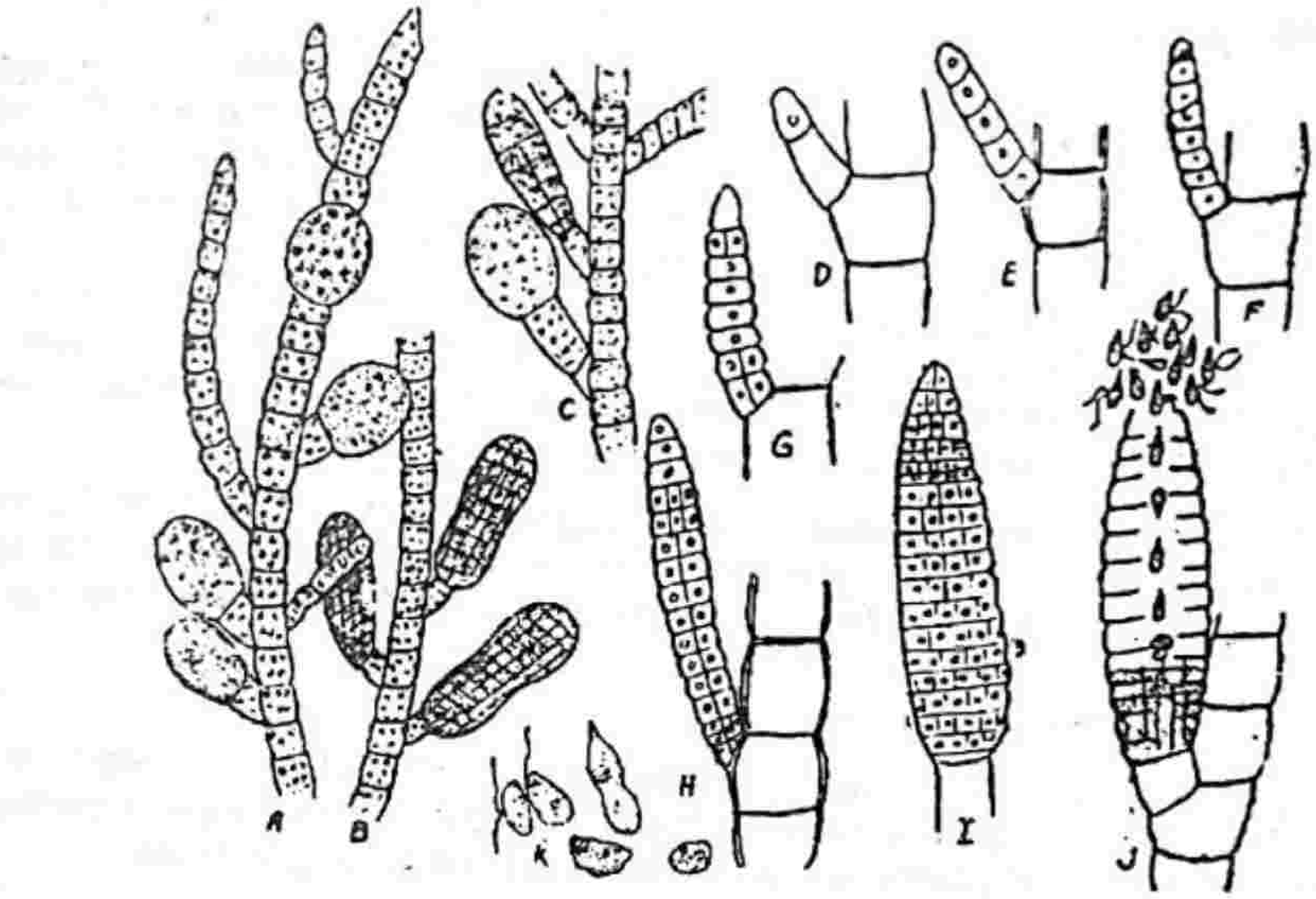
(V.V.I Node)

Growth of Thallus

The growth of the thallus in primitive brown algae is by an intercalary meristem at the base of a hair or filament. This type of growth is called trichothallic growth, e. g., in Ectocarpus.

Cell Structure

The cells are small, cylindrical or rectangular and uninucleate. The cell is surrounded by distinct cell wall composed of an inner cellulose layer and an outer pectin layer. The outer layer becomes slimy or gummy due to presence of pectic compounds. The most important constituent of the cell wall is alginic acid found in the outer layer of the cell wall. It forms a colloidal substance algin which is important economically. The reserve food is mannitol and laminarin starch. The golden brown in colour due to presence of dominant fucoxanthin. The other photosynthetic pigments are chlorophyll-a, -c, beta-carotene and other xanthophylls. Pyrenoid-like bodies are associated with the chromatophores.



● -> nucle
in cells

-> formed
multicellu

Fig. 4.30: Ectocarpus — Vegetative morphology and cell structure.

Reproduction

Ectocarpus reproduces asexually by zoospores and sexually by isogamy or anisogamy. The oogamous type of sexual reproduction is absent.

Asexual Reproduction

V -> sporangia

The asexual reproduction is either by means of biflagellate haploid zoospores produced in one-celled unilocular sporangia, or diploid zoospores formed in many-celled plurilocular sporangia. Both kinds of sporangia are present on the same diploid plant which is sporophyte. The sporangia are usually borne terminally and singly on lateral branches, but in rare cases these are borne seriately.

one celled

IMP

Unilocular Sporangia

A unilocular sporangium develops from a terminal cell of a short lateral branch. The sporangial initial enlarges in size and becomes globose or ellipsoidal. The number of chromatophores also increase. The nucleus of the sporangium divides meiotically to produce four haploid nuclei which undergo repeated mitotic divisions to produce 32-64 daughter nuclei. The cytoplasm of the sporangium cleavage and each bit surrounds a nucleus and a chromatophore to produce daughter protoplasts. Each daughter protoplast metamorphoses into a pyriform, biflagellate meiozoospore (zoospores produced as a result of meiosis). The flagella are laterally inserted and are of unequal size, the larger one directed forward and the smaller one is directed backward.

The meiozoospores are liberated from the sporangium through an apical pore in the sporangial in a gelatinous mass. After few moments these are separated from each other and swim freely in all directions. After the liberation of zoospores a new sporangium may be produced within the old sporangial wall.

(Multicellular)

Plurilocular Sporangia

The plurilocular sporangia are stalked or sessile, elongated, cone-like multicellular structures. Like unilocular sporangia these also develop from a terminal cell of a short lateral branch. The sporangial initial enlarges in size and undergoes repeated transverse mitotic divisions to produce a vertical row of 6-12 cells. These cells then divide by vertical and transverse divisions repeatedly to form a cone-like structure consisting of hundreds of small cubical cells arranged in 20-40 transverse tiers. Each cell represents a sporangium. The protoplast of each cell metamorphoses into a single, pear-shaped, diploid, biflagellate mitozoospore (the zoospores produced as a result of mitosis). The flagella are of unequal size and are laterally inserted.

The mitozoospores are liberated either through a terminal or a lateral pore formed in the wall of the sporangium. The zoospores just beneath the pore escape as irregular mass, whereas those away from it are released singly and in an orderly manner.

Germination of Zoospores

The zoospores formed in unilocular sporangia (meioszoospores) swarm for sometime and then come to rest on some solid object, withdraw their flagella and secrete a membrane around them. They germinate by the formation of a small germ tube.

Sexual Reproduction

Majority of the species are isogamous and homothallic.The gametes are produced in many-celled, elongated, sessile or shortly stalked, conical structures called plurilocular gametangia produced on haploid plants developing from the meiozoospores.

The development of gametangia is similar to that of plurilocular sporangia. These develop from terminal cell of a lateral branch. The gametangial initial gets inflated and divides mitotically by repeated transverse divisions to produce a vertical row of flat cells. These cells undergo repeated vertical and transverse divisions to form many hundred small cubical cells arranged in 24-40 transverse rows. The protoplast of each cell metamorphoses into a single, pyriform, biflagellate, haploid zoogamete. The flagella are laterally attached. The only difference between the zoospores and the gametes is that the gametes are relatively smaller in size. The gametes are liberated from the gametangium in through an apical pore formed in the cell wall of the sporangium.

Fertilization and Germination of Zygote

Fertilization results in a diploid zygote. The zygote germinates into a diploid sporophyte without undergoing any resting period.

Alternation of Generations

Ectocarpus shows isomorphic alternation of generations. The sporophyte is diploid and bears two types of sporangia, the plurilocular sporangia in which zoospores are formed as a result of mitosis (mitozoospores), and the unilocular sporangia in which the zoospores are produced meiotically (meiozoospores). The mitozoospores germinate into a diploid sporophyte whereas the meiozoospores germinate to give rise a haploid gametophyte plant that bears plurilocular gametangia. These gametophytes are similar to the sporophyte in morphology. Haploid gametes are produced in the gametangia which on fusion result in a diploid zygote that germinates into a diploid sporophytic plant. The diploid mitozoospores serve the purpose of reduplication of sporophyte generation. In some species the gametophyte generation is also reduplicated by the parthenogenetic germination of the gametes.

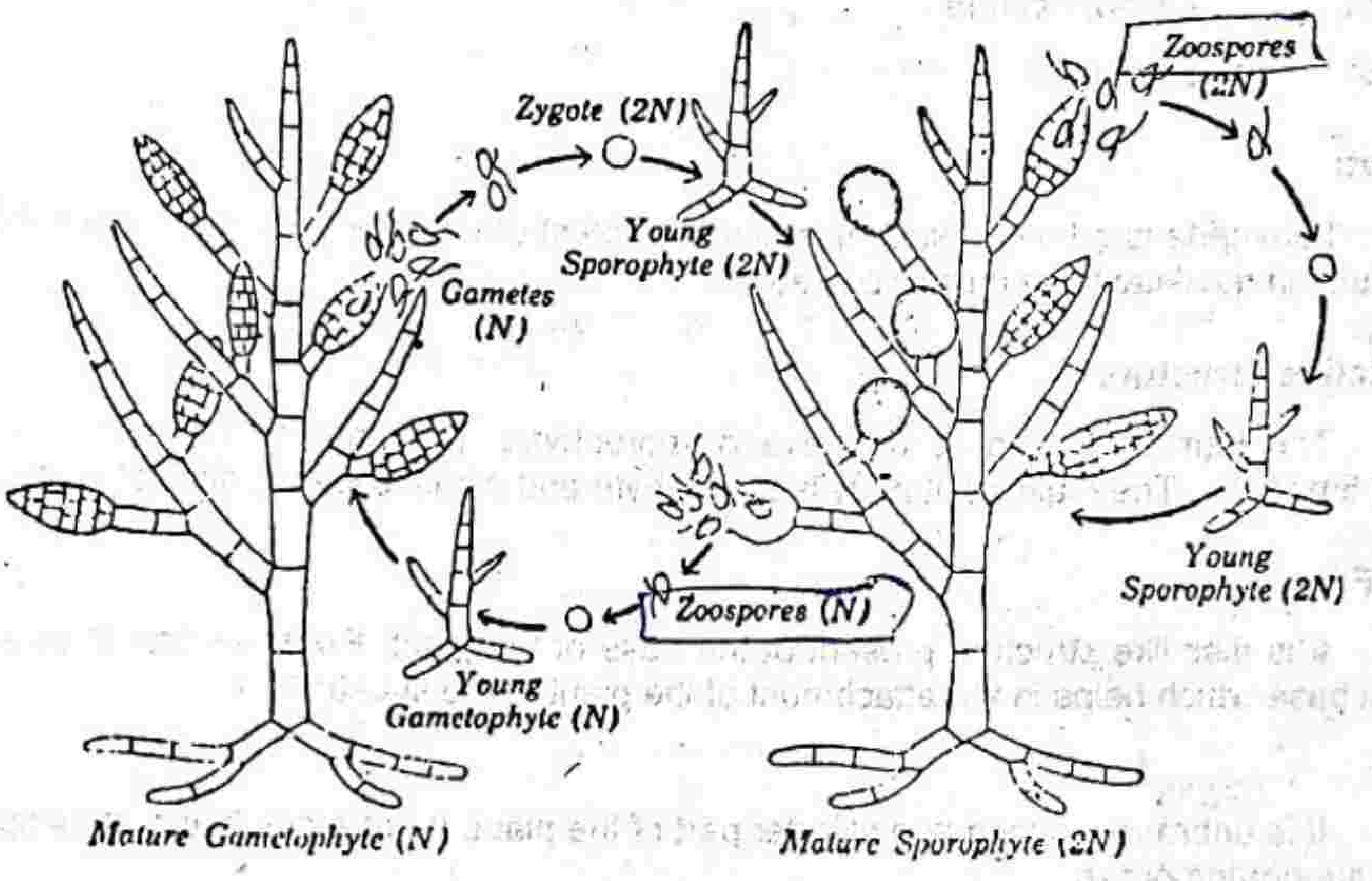


Fig. 4.31: Ectocarpus — Graphic life cycle.

LAMINARIA

Taxonomic Position

Division:	Phaeophyta
Class:	Heterogeneratae
Order:	Laminariales
Family:	*Laminariaceae*
Genus:	*Laminaria*

Habitat:

Laminaria is common kelp. It is common plant of cold water along the seashore. It is found in the Atlantic and Pacific oceans.

Vegetative Structure

The Laminaria plant is diploid and sporophytic. The body of Laminaria varies from0.5m to 9m. The main plant body is sporophyte and it has following distinct parts.

Hold Fast

It is disc like structure present at the base of the plant. Root like branches arise from it base which helps in the attachment of the plant to the substratum.

Stipe

It is unbranched long and slender part of the plant. It produces blade at its tip act as its supporting organ.

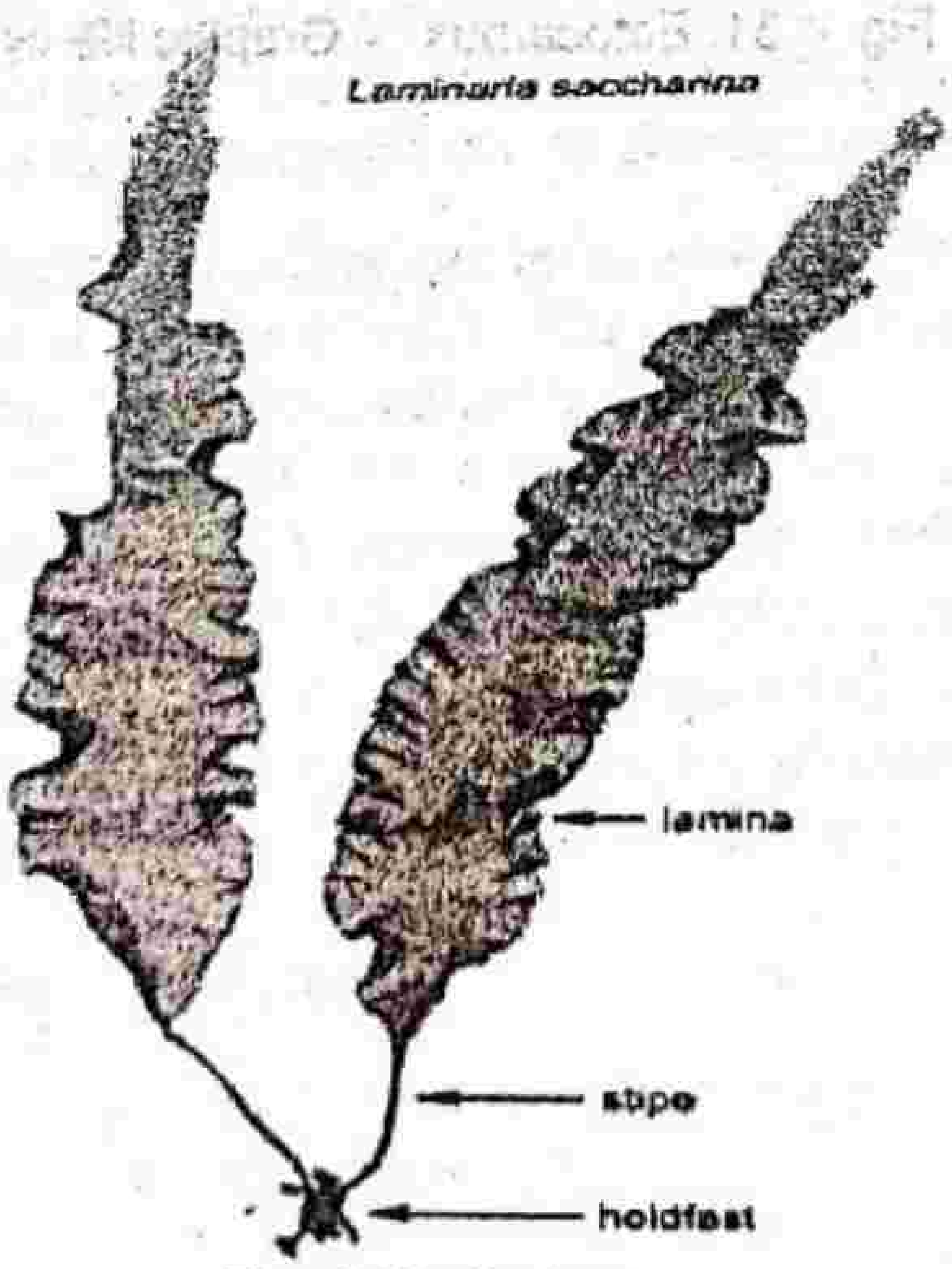


Fig. 4.32: A plant.

Blade or Lamina

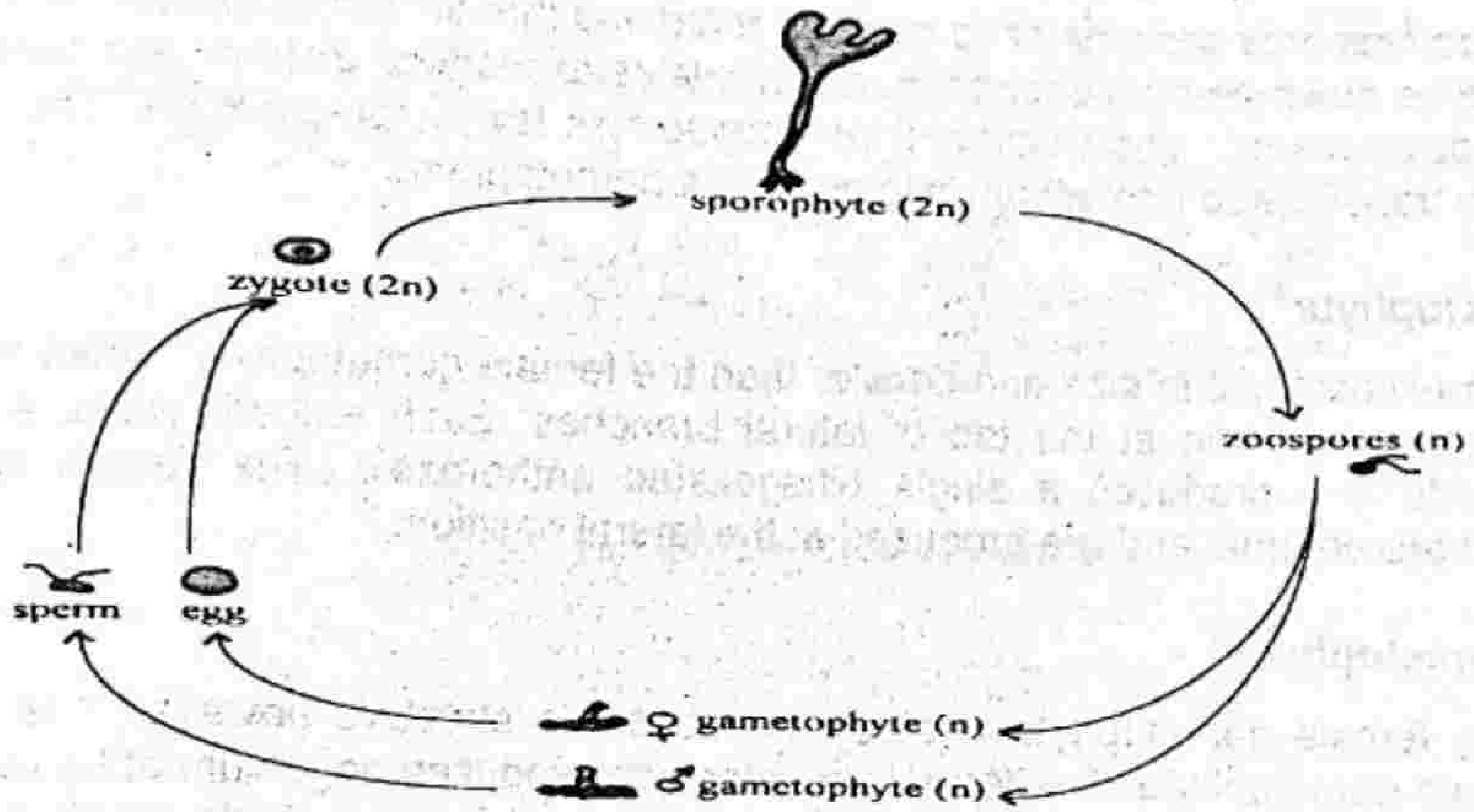
It is upper part of the plant. It is broader leaf like structure. It has smooth or wavy margin. In some species it is divided into many segments

Growth of Thallus

Growth of thallus is by an intercalary meristem present at the junction of stipe and blade. There is a continuous increase in the length of stipe by the activity of meristem however the length of blade remains approximately constant because increase in length at the base almost equals the abrasion at the apex. The blades of most species grow for one year and they disintegrate after the plant has discharged its zoospores

Reproduction

In Laminaria there is distinct alternation of generation. Its life cycle is completed into two distinct stages. First stage is sporophyte while second stage is gametophytic generation. The two generations are morphological distinct phases and such type of alternation of generation is called as heteromorphic alternations of generation.



Lamanaria reproduce both by asexual and sexual means

1. Asexual Reproduction

Lamanaria reproduce asexually by the formation of spores. The spores are produced in the zoosporangia. At the time of reproduction, numerous zoosporangia are produced on both surface of blade in groups called as sori. Among the sporangia elongated hair like structure called as paraphysis are also produced in the sori. In each zoosporangium 32-64 biflagellate zoospores are produced.

Development of Sporangium.

Each epidermal cell of young soral area acts as paraphysis initial.

It produces a finger like outgrowth that divides into an upper and a basal cell by a transverse wall at its base. The upper cell elongates to form an erect unicellular paraphysis with a distinct mucilaginous cap at its swollen apex. The paraphyses produced arrange themselves in a palisade-like layer.

The basal cell develops into club-shaped unilocular sporangium. The single nucleus of sporangium undergoes meiosis to produce four haploid nuclei, each of which divided by mitosis to produce 32 or 64 nuclei. . In each zoosporangium 32-64 biflagellate zoospores are produced.

Liberation of Zoospores

When the zoospores are mature, the wall of the sporangium breaks at the apex and zoospores are liberated out. They swim in water for a certain period and then secrete a wall around each spore They settle on the substratum and germinate to produce gametophyte of Laminaria.

2. Sexual Reproduction

Gametophytic Stage

Germination of Zoospores

The zoospores germinates to produce male and female gametophytes. When the zoospore settle down on the substratum, it germinates to produce a short germ tube. The germ tube develops into short filament, which also has few small branches. The whole body is than transformed into either male or female gametophyte.

Male Gametophyte

It is microscopic in size and smaller than the female gametophyte. When mature it bears many antheridia at the top of lateral branches. Each antheridium is a small rounded body and produces a single biflagellated antherozoid. The flagella on the antherozoid are unequal and are produced at the lateral position.

Female Gametophyte

The female gametophyte is also microscopic in structure however, it is larger than the male gametophyte. The female gametophyte produces oogonium at he terminal or intercalary position. Each oogonium is a large body and forms a single oosphere. The oogonium is surrounded by a mucilaginous covering which form a cuplike structure at its apex. Whenmature, the oosphere is partially discharged out of the oogonium and remains attached to its apex.

Fertilization

At the time of fertilization, the antherozoids swim to the oogonium. One antherozoid fuses with oosphere. As a result an oospore (2N) is formed.

Germination of Oospore

The oospore germinates and form a short filament. It is separated from the oogonium. From its lower side rhizoids are arises which help in the attachment of filament to a substratum. The filament is then developed into a complete sporophyte plant.

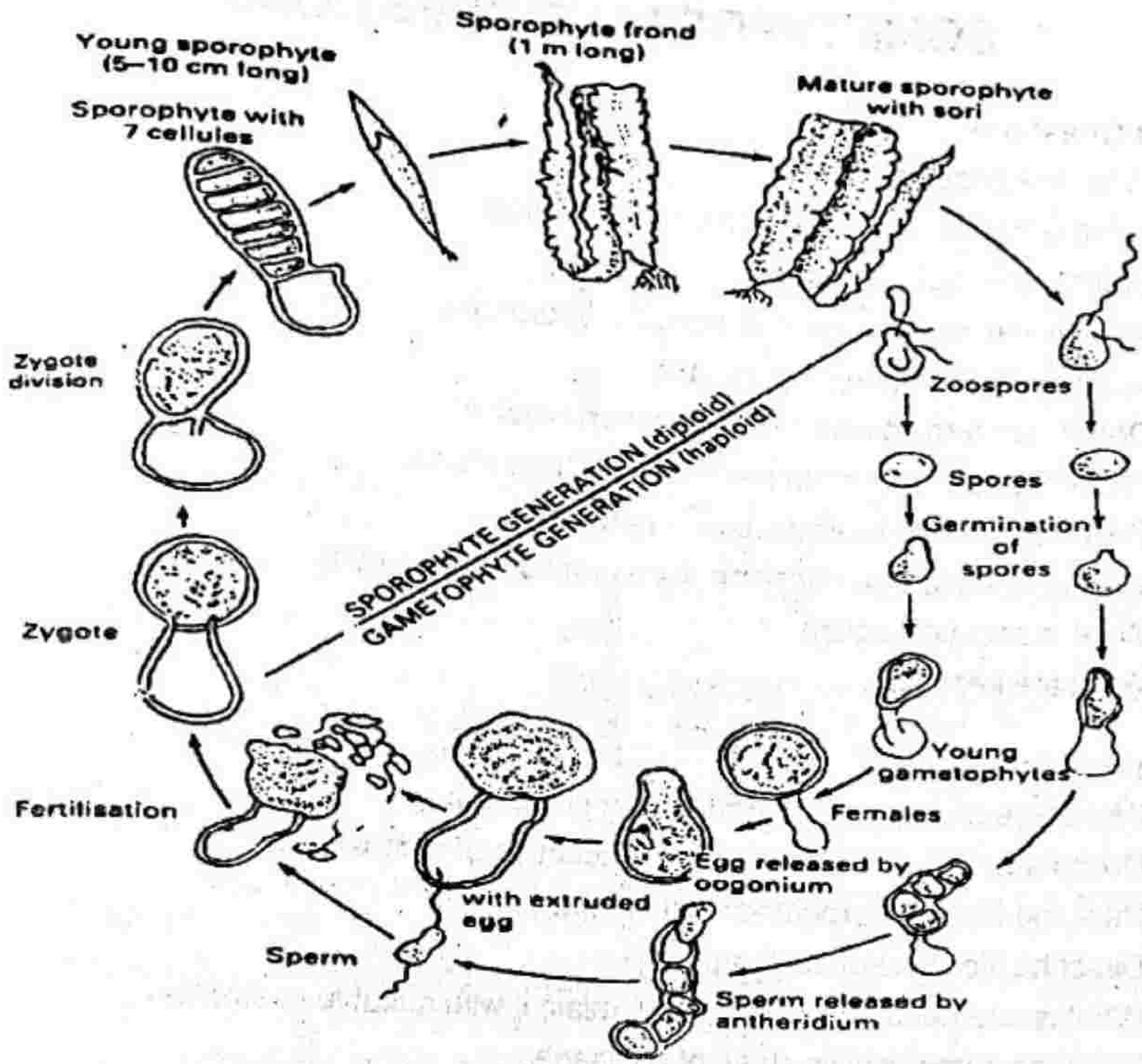


Fig. 4.33: Life Cycle of Laminaria

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are phaeophyta.
2. What is the taxonomic position of ectocarpous.
3. What is unilocular sporangia.
4. What is the importance of plurilocular sporangia.
5. What is the structure of Laminaria.
6. Define isomorphic alternation of generations.
7. Which types of pigments are found in phaeophyta.
8. Describe asexual reproduction in laminaria.
9. What is chemical composition of cell wall of phaeophyta.
10. What is zoosporangium.
11. What are kelps.

B. Long Questions

1. Write note on auxospore formation in pinnularia.
2. Describe structure and asexual reproduction of ectocarpous.
3. Describe sexual reproduction in Laminaria.
4. Describe life cycle of ectocarpous.
5. What is alternation of generation. Explain it with suitable example.
6. Describe gametophytic stage of laminaria.
7. Describe life cycle of laminaria.

✓ * Fund ✓

RHODOPHYTA

I. O

GENERAL ACCOUNT

occurrence:

1. The red algae like brown algae are predominantly marine, however some species like Batrachospermum are freshwater and are found in streams, lakes and streams. Marine species flourish in both littoral and sub-littoral zones.
2. Many species precipitate calcium carbonate on their cell surfaces and become calcareous. These are important in reef formation. ✓
3. The thallus is fundamentally filamentous and is built up in two planes (uniaxial type, in which there is a central branched main axis which may be corticated or uncorticated, e. g. in Batrachospermum, and multiaxial type, in which there is a mass of central filaments from which lateral filaments radiate out, e. g., in Polysiphonia) However unicellular and colonial forms also found.
4. The growth of the thallus is nearly always apical except in Bangiophycidae. Branching is nearly always monopodial.
5. *✓ The cell is typically eukaryotic. The protoplast is bounded by a two layered cell wall the inner consisting of cellulose and outer of pectic material. The cell wall of some of the red algae contains xylans.
6. The cells are uninucleate in some of the primitive forms such as Nemalion and Batrachospermum but in most of the genera these are multinucleate e. g., in Polysiphonia. In majority of the species a large central vacuole occupies the center of the cell.
7. The cytoplasm is restricted to the periphery in the form of a thin layer next to the cell wall.
   → pig-contain/light-refl.... cells
8. The chromatophores are commonly band-shaped and parietal, however in some primitive Nemalionales and Bangiales they are stellate. (radiating → star shaped)
9. The photosynthetic pigments are chlorophyll-a, chlorophyll-d (when present) and the carotenoids. These are masked by red billiprotein pigments, the r-phycoerythin and r-phycocyanin and allophycocyanin.
10. The reserve food is stored as a complex carbohydrate, the floridean starch. The reserve food usually occurs in colourless cytoplasm at the surface of the plastids rather than within them.
11. Electron microscopic investigations have revealed the presence of dictyosomes, endoplasmic reticulum and mitochondria.
12. g The members of the class reproduce usually by asexual and sexual means of reproduction. The vegetative reproduction is very rare.
13. The red algae produce one or more kinds of non-motile ① asexual spores. These include:

i. Carpospores;

These spore develop from the zygote. The zygote nucleus divides meiotically into haploid nuclei. These nuclei pass into gonimoblast initials which develop into gonimoblast filaments. The apical cell of this filament develops into a carposporangium and bears a haploid carpospore, for example in Batrachospermum.

ii. Monospores:

These spores develop singly in monosporangium, e. g., in Batrachospermum.

iii. Neutral Spores:

These spores are formed by direct transformation of a vegetative cell, e. g., in Bangia.

iv. Tetraspores:

(2n) 4-sacs

These spores are produced on a diploid plant in tetrasporangia in which four spores are produced, e. g., in Batrachospermum.

v. Bispores and Polyspores:

In certain plants two spores are produced in a sporangium. These spores are called bispores. In some other species many spores are produced per sporangium. These are called polyspores.

2

♂ = move
♀ = still

1. The sexual reproduction in red algae is unique, highly advanced, and of complex oogamous type. The reproductive organs are characteristics of this group. The male reproductive organs are called spermatangia and the female ones as carpogonia. Both the reproductive organs are usually present on separate plants, but they may occur on the same plant.
2. The zygote divides directly or indirectly into spores, the carpospores.
3. The reserve food is a carbohydrate, the floridean starch occuring at the surface of the plastids in the cytoplasm. again!
4. Motile reproductive bodies are entirely absent in this class.

2

id.p

BATRACHOSPERMUM

Red ✓ 3

Taxonomic Position

Division: Phodophyta
Class: Rhodophyceae
Order: Nemalionales
Family: *Batrachospermum*
Genus: *Batrachospermum*

Habitat:

vary in size from a few to several cm. in length.

Batrachospermum (Gr. batrachos=frog + sperma=seed) is a fresh-water alga found generally in cold running streams of water. It prefers cool, well-aerated, clean water and shady places. Batrachospermum has about 40 species and the *B. moniliforme* is the most common one. The thallus is in the form of a spawn-like mass covered with soft and thick mucilage, therefore is commonly known as frog spawn.

PLANT BODY

The thallus is violet or blue-green in colour. It is soft, thick and gelatinous. The plants growing in deep waters are reddish. The mature thallus appears as chain of beads. The thallus shows uniaxial arrangement and heterotrichous habit. There is a reduced prostrate system which helps the plants to attach to the substratum. The erect system is branched and floats freely in water.

The main axis is corticated and consists of a row of elongated cylindrical cells. It is differentiated into nodes and internodes and is frequently branched. Two types of branches arise from the nodes

i. The Branches of Limited Growth:

These arise in whorls from nodes and after growing for sometime often terminate into long hairs. They consist of monoliform cells arranged in form of chains of beads. All the branches of a whorl are almost same length and together form a globose mass called a glomerule.

ii. The Branches of Unlimited Growth:

These branches arise from the basal cell of branch of limited growth. These are also differentiated into nodes and internodes and corticated. From the nodes branches of limited growth arise. The cells of branches of unlimited growth are comparatively longer than those of branches of limited growth.

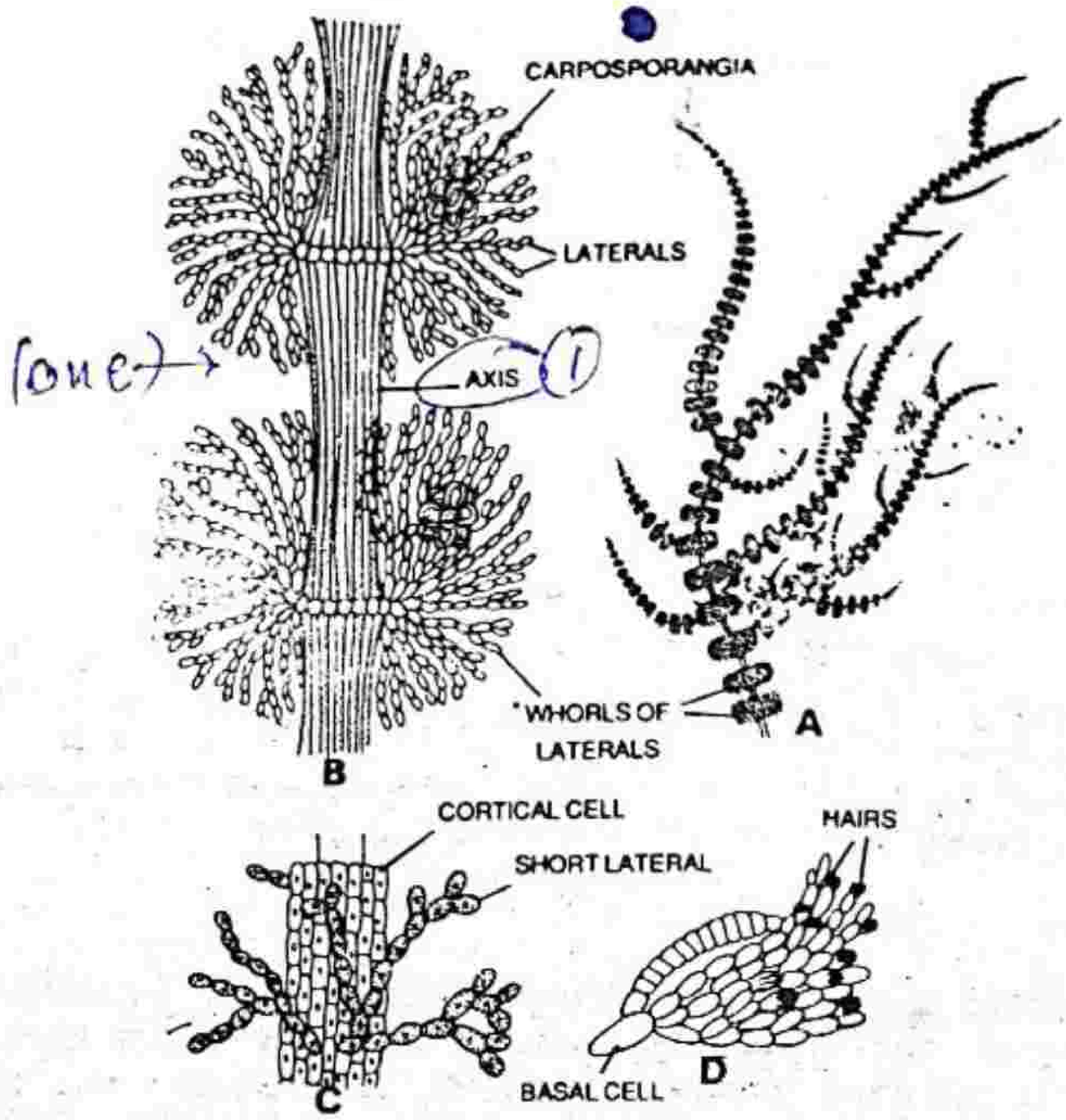


Fig. 4.34: Batrachospermum — Vegetative morphology.

Growth of Thallus and Origin of Branches

The growth of the thallus is by a hemispherical dome-shaped apical cell of the axial filament. A little distance behind the apical cell 4-6 small protuberances develop on its lateral side which are cut off by a transverse wall to form pericentral cells, each

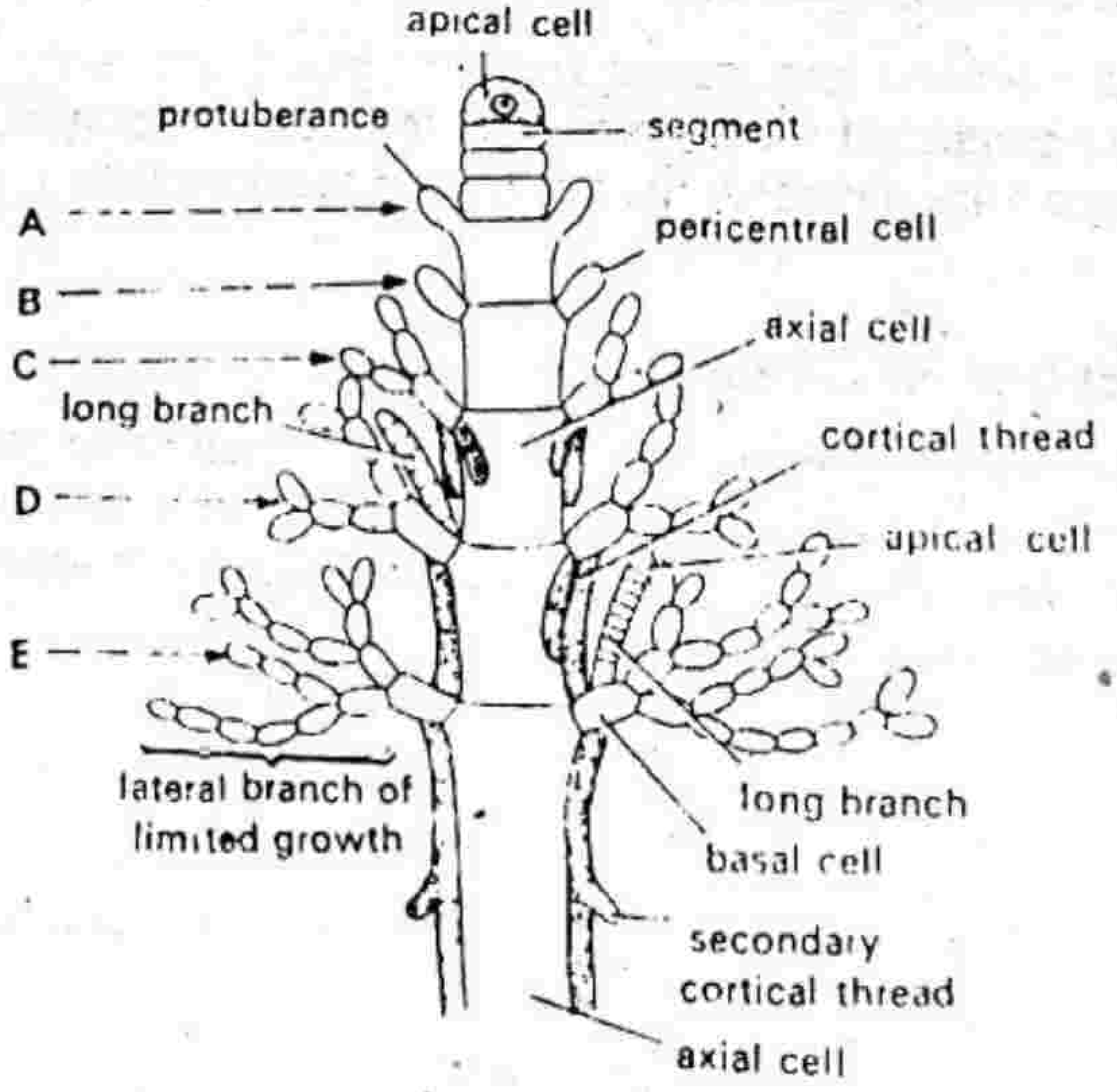


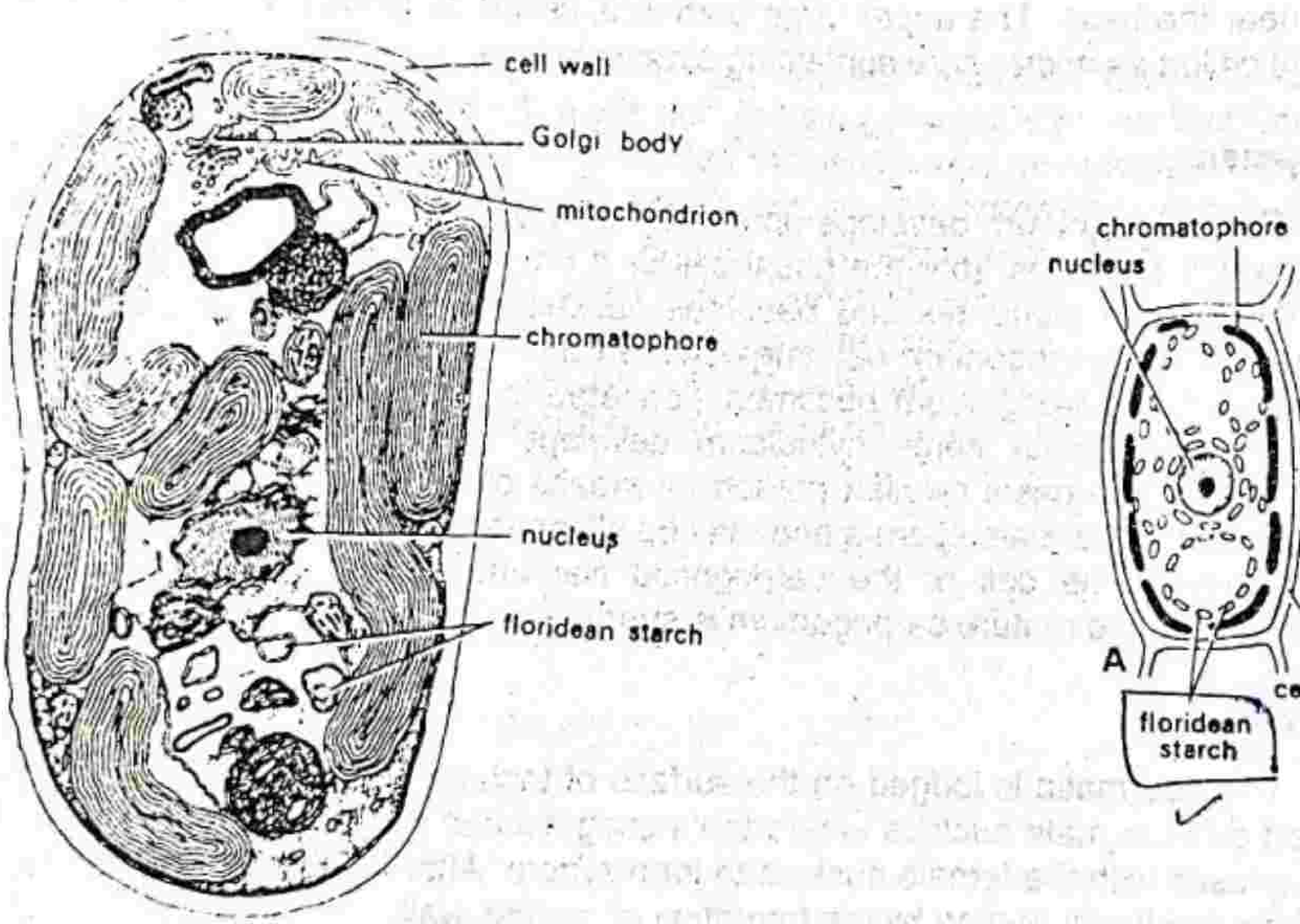
Fig. 4.35: Batrachospermum — Apical growth.

functioning as initial of a branch of limited growth. It divides repeatedly to produce a small branch and itself remains small and is known as basal cell of the branch of limited growth. The axial segment elongates to form an elongated, cylindrical internodal cell of the axial filament. As a result of the elongation the pericentral cells are separated from one another and give the appearance of a node bearing whorls of branches of limited growth. A branch of unlimited growth arise from the basal cell of the branch of the limited growth. Cortical filaments arise from the basal cell of the branch of limited growth. These run down the axial filament to envelope the internode.

Cell Structure

1.0

The protoplast is surrounded by plasma membrane which is bounded by two layered cell wall. The outer layer is formed of pectic compounds and the inner of cellulose microfibrils. Each cell is uninucleate and contains many chromatophores which are parietal in position. A single pyrenoid is present in each chromatophore. The photosynthetic pigments found in the chromatophores are chlorophyll-a, chlorophyll-d, and characteristic pigments of the red algae the r-phycocyanin and r-phycoerythrin. The reserve food is in the form of Floridean starch and is found scattered in the cytoplasm. Golgi bodies and mitochondria are also found.



X Fig. 4.36: Batrachospermum — Cell structure.

Reproduction (veg)(absent) ?

Motile reproductive bodies are entirely absent in the batracospemum. Batrachospermum reproduces by asexual and sexual means of reproduction.
① ②

Sexual

Sexual reproduction is oogamous type. Palnt may be homothelic or heterothallic.

Antheridia

The male sex organ anteridia or spermatengia are small unicellular structure. They arises at the tip of side branches either singly of in group. A mature spermatangium is thick walled, small, colourless and rounded. The terminal or sub-terminal cells of branches of limited growth act as spermatangial initials. Each initial develops a projection, its nucleus divides mitotically and one of the daughter nucleus passes into the projection which is later cut off by a septum.The content of each antheridium are metamorphosed into single, uninucleate, nonmotile structure called as spermatium.

Liberation of spermatium

The spermatia are liberated, by the rupturing of antheridial wall and they are carried by the water currents. They are lodged on the surface of female reproductive organs.

Carpogonia

The female reproductive organ is called as carpogonium. It is unicellular and arises at the tip of some branches. Each carpogonium consists of elongated cell, which is jointed near the base. The upper large portion is called as tricogyne. The lower globular portion is called as microspore containing single nucleus.

Development

The carpogonium develops on a 3-5-celled branch called carpogonial branch or procarp which develops from the basal cell of a branch of limited growth. The terminal cell of this branch elongates and becomes flask-shaped to form a carpogonium. The basal part of the carpogonium becomes swollen and contains an egg nucleus while the upper part of the carpogonium becomes elongated to form the trichogyne. Later on the egg nucleus alongwith some cytoplasm develops into an egg. The trichogyne is separated from the basal swollen portion by means of a constriction. The trichogyne is meant to receive the male sperms and may be slipper-shaped, club-shaped, cylindrical or spatula-shaped. The cell of the carpogonial filament next to the egg cell is called supporting cell. The mature carpogonium is surrounded by vegetative filaments its base.

Fertilization

The spermatia is lodged on the surface of trichogyne. The wall between the two dissolved and the male nucleus enters the trichogyne and move towards the base. In the base it is fuses with the female nucleus to form zygote. After fertilization, the trichogyne is cut off from the basal portion by the formation of a cross wall.

Formation of Cystocarp

The zygotic nucleus is divided by meiotically and four nuclei are formed. One of the daughter nuclei migrates into a proturbrance produced on the carpogonium. It is separated from the rest of the mass by the formation of septum. The other nuclei remain in the carpogonioum and divided again and again. The nuclei are then transferred into new protuberance and this process is repeated by several times. These protuberance, which is called as initials of gonimoblast filaments by further cell divisions produced small branched filaments called Gonimoblast filament. The carpogonium along with gonimoblast filament is called as Cystocarp.

Formation of Carpospore

Each filament of gonimoblast filament produce a single nonmotile spore called as carpospore.

Chantransia Stage

The carpospores are liberated as a naked mass of protoplast by the rupture of cell wall. They come to lye on the surface, secrete a cell wall and developed into a mass or sole of parenchyma tissues. Simple branches are arise from the pad of tissues. These filament form a Chantransia stage which is resembled to another alga called Chantransia.

Monospore formation

Each terminal cell of short lateral branches produced a single nonmotile spore, called as monospore. After liberation it produced Chantransia stage again.

Terminal cell of the lower branches of Chantransia stage may function as an apical cell and give rise to the new adult plant.

Alternation of Generations

Batrachospermum plant is free-living haploid gametophyte. It bears spermatangia and carpogonia in which male and female gametes develop that unite to form the diploid zygote. The zygote nucleus divides meiotically and gonimoblast filaments are formed. The terminal cells of these filaments act as carposporangia and in these haploid carpospores develop. This plant is the carposporophyte. The carpospore germinate to produce the haploid Chantransia stage. The mature Batrachospermum plant arise from filament of Chantransia stage. During the life cycle there are two haploid phases, the gametophyte and the carposporophyte alternating with only one diploid phase represented by the zygote. Therefore, the life cycle of the Batrachospermum is haplobiontic or diphasic type.

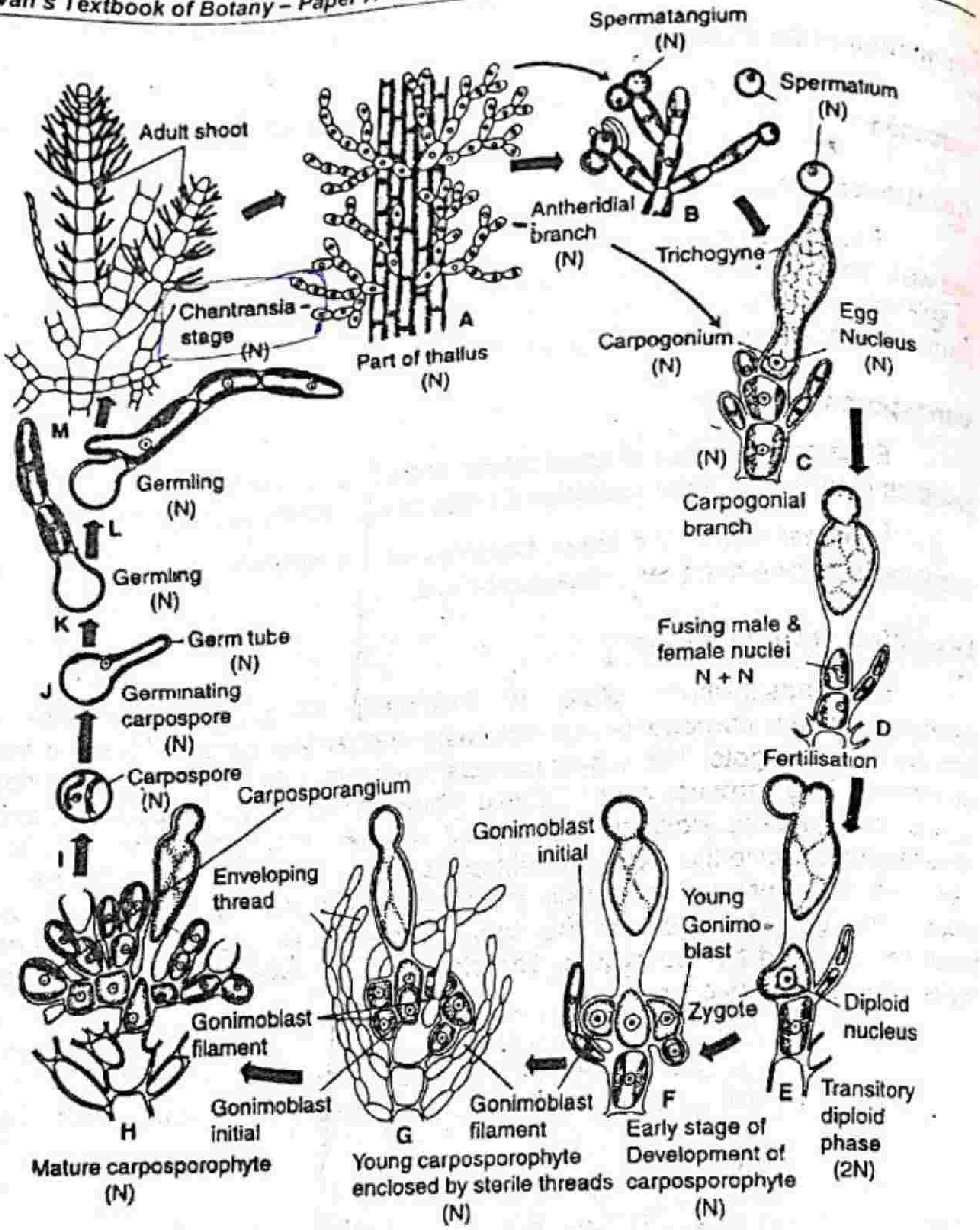


Fig. 4.37: Batrachospermum Life Cycle.

① Brown ② purple
③ Red-algae

POLYSIPHONIA +(Ectocarpus)

pheophyta:-
phyta

Taxonomic Position

Division:	Position
Class:	rhodophyceae
Order:	Ceramiales
Family:	*Rhodomelaceae*
Genus:	*Polysiphonia*

Habitat :-

Polysiphonia is a marine alga commonly found along the Karachi coast. It grows attached to the rocks, wood or epiphytically. The plant is brownish, purple or red in color.

Structure

The plant body is in the form of erect branched filaments which are attached to the substratum by a disc like basal portion often called as decumbent portion.

Rhizoid

The basal attachment disc is formed of several unsepate, branched rhizoid.

Erect branch

The vertical portion is formed of laterally branched axis which is polysiphonous. The axis if formed of bundle of filament or siphon. The cell of the same filament lie at the same level forming tires of cells.

Central Siphon

The central siphon represent the primary axis which is surrounded by pericentral filaments in one or two layers.

Corticating Filament

The pericentral filament is further surrounded by one or more layers of much narrowing filaments called corticating filaments.

Trichoblast

The branches often bear uniseriate, multicellular, dichotomously branched short filament which look like fine hair and is called as trichoblast. The individual cell of trichoblast is always uni-nucleated and generally colorless.

Cell Structure

Each cell is surrounded by a well developed cell wall which is mainly formed of cellulose and pectin material. Young cell is always uninuclated. Each cell contain several discoid chloroplast containing chlorophyll a, d, carotene, xanthophylls, phycoerythrine and phycocyanine. Pyrenoids are absent. The reserve food material is in the form of floridean starch.

~~Spermatium firmly stick on the surface of trichogne. The wall b/w spermatium and trichogne dissolves and male nuclei migrate into basal carpogonium.~~

~~⇒ fuse → (2n) zygot~~

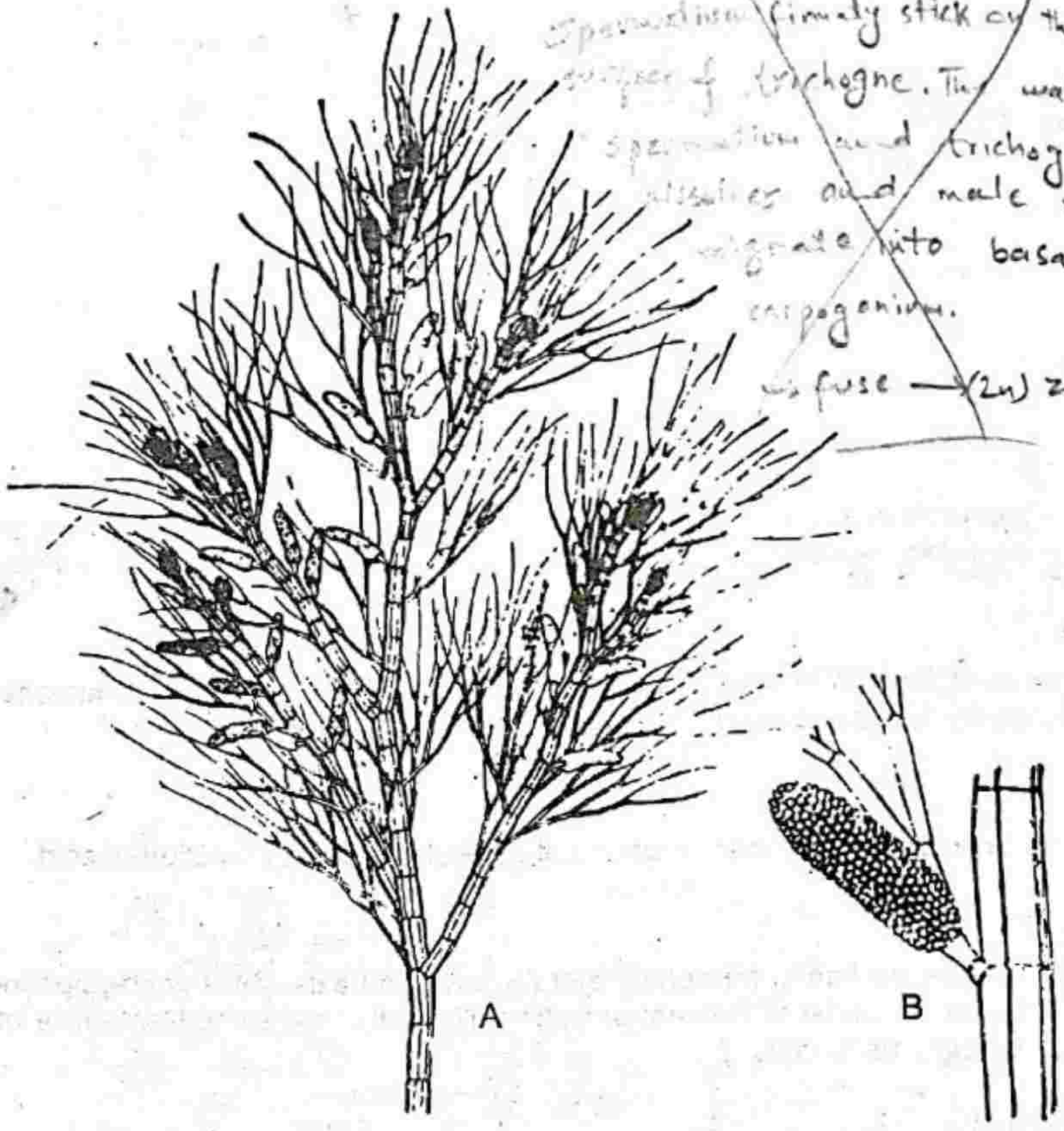


Fig. 4.38: Polysiphonia

Reproduction

Sex

Asex There is isomorphic alternations of generation of gametophytic (haploid) and sporophytic(diploid) generations. Both the generations are morphological similar.

Sexual Reproduction

♂ Majority of the species are heterothallic.

♀ Spermatangia (male plant produced spermatangia) (♀ = carpogonium)

The male sex organ or spermatangia re produced in cluster on fertile branches. Each fertile branch has a central row of cells which are surrounded by pericentral cells. Each pericentral cell cut off one or more spermatengial mother cells. Each mother cell produced one to four spermatangia. The content of each spermatangium are transformed into a single nonmotile spermatium. The spermatium is released by the dissolving the wall of spermatangium and is carried by water current to the carpogonium.

→ fertile branch

↳ central row of cell surround by (pericentral cells) ↳ cut off → 4 spermatangia ↓ spermatium ↓ spread water

Carpogonia (♀)

The female sex organ is carpogonium are produced singly on the female fertile branch. The apical cell of the carpogonial filament is transformed into a carpogonium. Each carpogonium is a flask shaped structure having a basal swollen portion contain egg, and an upper elongated neck called trichogyne.

Fertilization

When the spermatium logged on the trichogyne, the wall between the two dissolves. The spermatium nucleus along with the surrounding cytoplasm enters the trichogyne and reached to the basal portion where the egg is fertilized. The diploid zygotic nucleus is formed which divided into two nuclei.

Several small protuberance are produced on the surface of the placental cell and diploid nucleus is migrated into the protuberance. Septa are produced and function as initial of gonimoblast filament. It undergoes some transverse division producing a short filament known as gonimoblast filament. The terminal cell functions as carpogonium which produced a single non-motile diploid carpospores. The carpospores are liberated by the rupturing of carpogonial wall.

gametophyte The carpospores germinate produce the sporophytic plant.

Asexual Reproduction

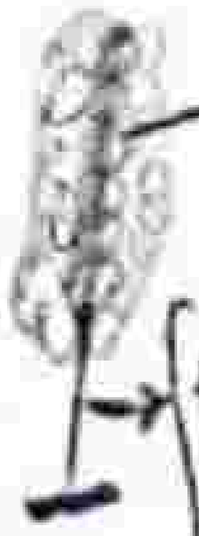
The sporophyte is known as tetrasporophyte because it produced tetra spore. These spores are nonmotile and are produced in tetrasporangium.

Tetrasporangia are produced from the fertile cell. Only one tetrasporangium is produced in each tire of cell. Several tetrasporangia are produced on each branch on successive tires.

The fertile cell is smaller than the other cell. This cell cut off a small peripheral cell to the out side and one or two large cover cells. It divided transversally into two cells of unequal size. The lower smaller cell becomes the stalk cell while the upper lateral cell becomes the tetrasporangium. The nucleus of the tetrasporangium undergoes meiosis producing four haploid nuclei. Each nucleus along with cytoplasm transformed into tetraspore. The tetraspores are liberated by the rupture of the sporangial wall.

The tetra.spore germinated to produce gametophytic plant body and the life cycle is completed.

spermatagia:- ♂



→ central row of cells surrounded by (perifentral cells)
→ [fertile branch]

cut off
⇓
4 spermatangia
↓
([illegible]) Spermatangium
↓
wall disolve & spermatium by water towords carpogonium ([illegible])

capogonia: ♀ (produce singly)
- ♀ sex organ carpogonium.
- flask shaped with basal swollen portion contain egg. with upper elongated (trichogne) neck.

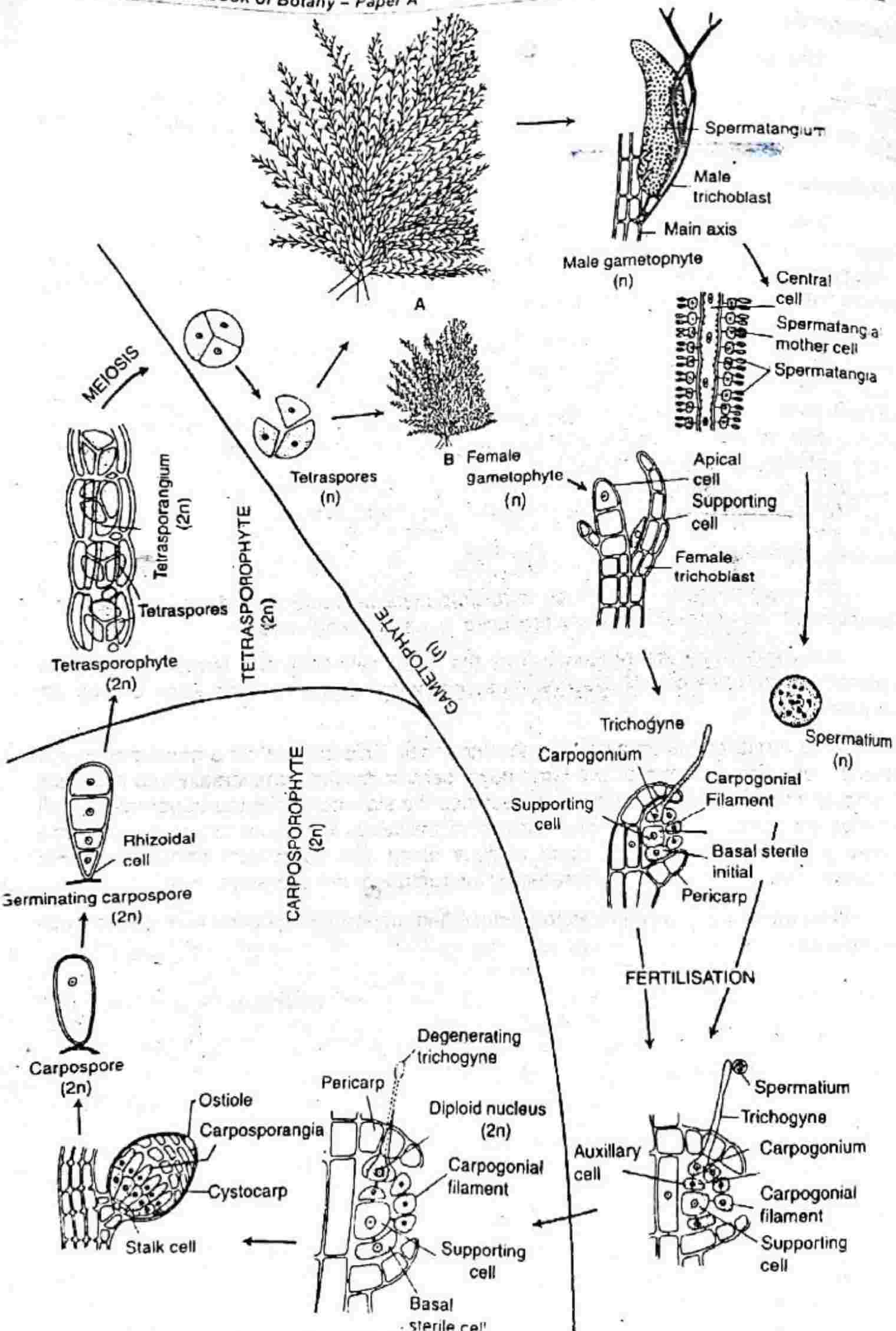


Fig. 4.39: Life Cycle of Polysiphonia.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are Rhodophyta.
2. What is the taxonomic position of polysiphonia.
3. What is tetraspore.
4. What are the bispore and polyspore in rhodophyta.
5. What is the structure of carpogonium.
6. Define alternation of generations.
7. Which types of pigments are found in rhodophyta.
8. Describe asexual reproduction in batracospermum.
9. Draw diagram of batrachospermum.
10. What is cystocarp.
11. What is chantransia stage.
12. What is corticating filaments.
13. Why polysiphonia is so called.

B. Long Questions

1. Describe structure and asexual reproduction of batrachospermum.
2. Describe sexual reproduction in batrachosperemum.
3. Describe life cycle of batrachospermum.
4. What is alternation of generation. Explain it with batrachospermum.
5. Describe gametophytic stage of polysiphonia.
6. Describe life cycle of polysiphonia.
7. Describe structure of polysiphonia.

SECTION VI

THE FUNGI

Chapter 5

THE FUNGI

GENERAL CHARACTERS

Fungi is derived from the latin word FUNGOUR which means to flourish. The word was primarily used with reference to MUSHROOMS which develop overnight. However, from the Greek word MYKES, the term mycology was derived for the study of fungi. Pier Antonio Michell, an Italian botanists, first published his research on fungi in 1729 entitled *Nova Plantarum Genera*. He is regarded as father of the science of mycology.

The fungi (sing: fungus) are eukaryotic, achlorophyllous organisms consisting of filamentous, septate or aseptate somatic structures called hyphae, that form a wooly mass, the mycelium in most cases.

The hyphae are surrounded by cell walls formed of chitin or cellulose, or both. They reproduce sexually and asexually by formation of spores. About 5100 genera and more than 50,000 species of the fungi are known today.

Occurrence

The fungi are Ubiquitous i.e. present almost everywhere on the earth. Fungi grow in a wide variety of habitats such as water, soil, dead and decaying organic matter, on other living organism. They also cause serious diseases.

Since the fungi are unable to manufacture their own food, therefore these live as saprobes on non-living organic matter. As parasites itinfect plants and animals including the human beings, causing diseases. The fungi require a sufficient amount of organic food to survive; therefore they digest the organic food outside their bodies by secreting the enzymes (extracellular enzymes) and making the organic matter soluble so that it may be absorbed into their cells easily and effectively.

Plant Body

The vegetative phase of fungus is a thallus. There is no differentiation into stem, root or leaves and the vascular tissue is absent such a plant body is called as thallus.

Unicellular Thallus

In some fungi the thallus is single cell spherical structure. e.g. Yeast.

Filamentous Thallus

Majority of fungi have a multicellular plant body. Which is composed of thread like, tubular filaments called hyphae, present in the form of a loosely woven mass, the mycelium.

Hyphae

A hypha is made of a thin transparent, tubular wall filled or lined with a layer of protoplasm. It may be septate or aseptate. In simpler fungi the hyphae are aseptate (without cross wall) and coenocytic (Gr. koinos=common + koite=couch), i. e., many nuclei are embedded in the cytoplasm. However, the septa are formed at the base of reproductive organs in simpler fungi. In more complex groups the hyphae are septate, i. e., divided into cells or compartments by cross walls called septa (sing. septum; L. septum=hedge, partition).

Mycelium

The mass of hyphae constituting the vegetative body (thallus) of a fungus is called the mycelium (pl. mycelia). If the mycelium penetrates the host tissue, it is said to be intracellular and if it confines itself to the intercellular spaces, it is termed as intercellular mycelium.

Cell Structure

The fungal cells are typically eukaryotic and lack chloroplasts. It has following demarcations.

Cell wall

The protoplast is enclosed by cell wall. In majority of fungi the wall lake cellulose but contain a form of chitin known as fungus cellulose. The formula of fungus chitin is $(C_{22} H_{54} N_4 O_{21})_n$. It is polysaccharide based on nitrogen containing sugar (glucosamine). In addition to chitin the pectin, protein, lipids, cellulose, callose and minerals are also present.

Protoplast

Plasmalemma

Inner to the cell wall is the plasmalemma which is a unit-membrane composed of proteins layers separated by a lipid layer.

Vacuole

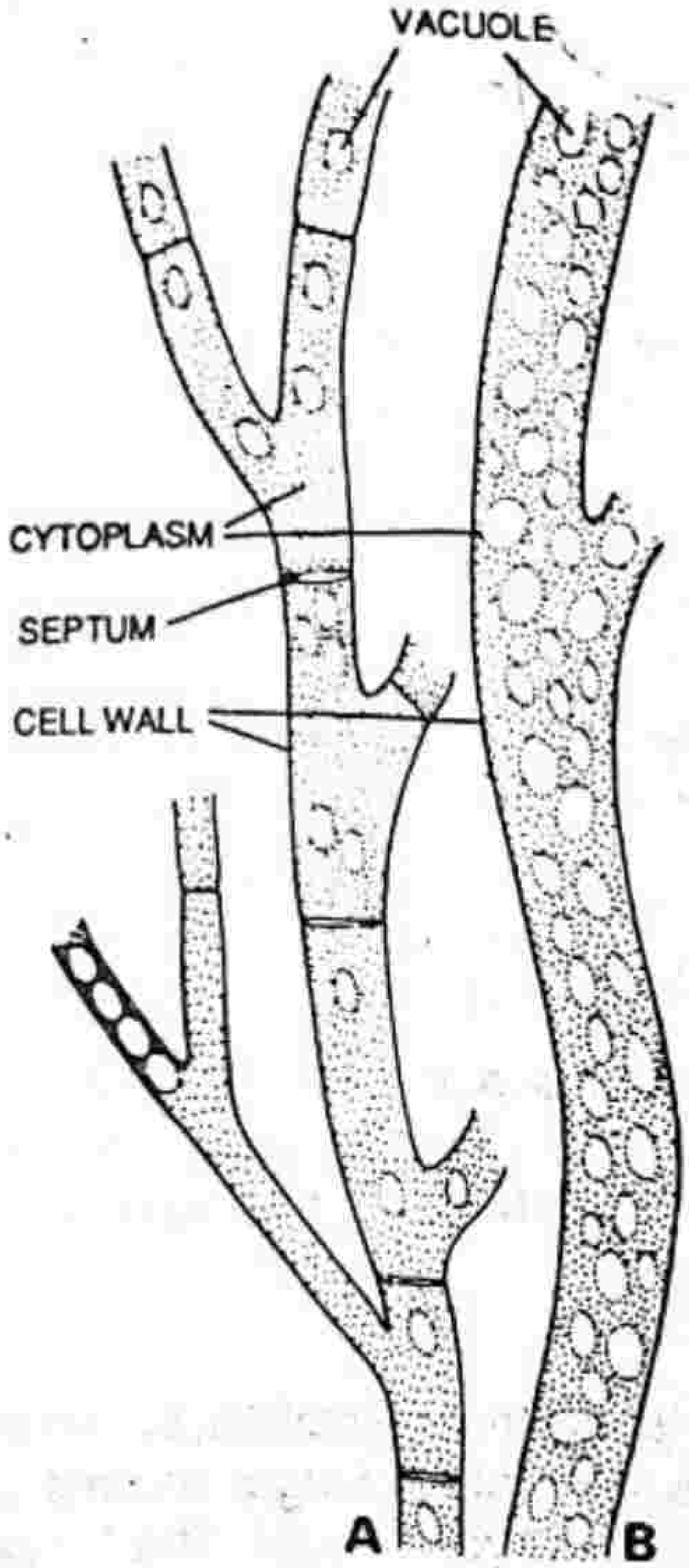
The cytoplasm of young hypae lacks vacuole. However, a large central vacuole bounded by tonoplast is found in some fungi while in other cases many small vacuoles are present.

Endoplasmic reticulum

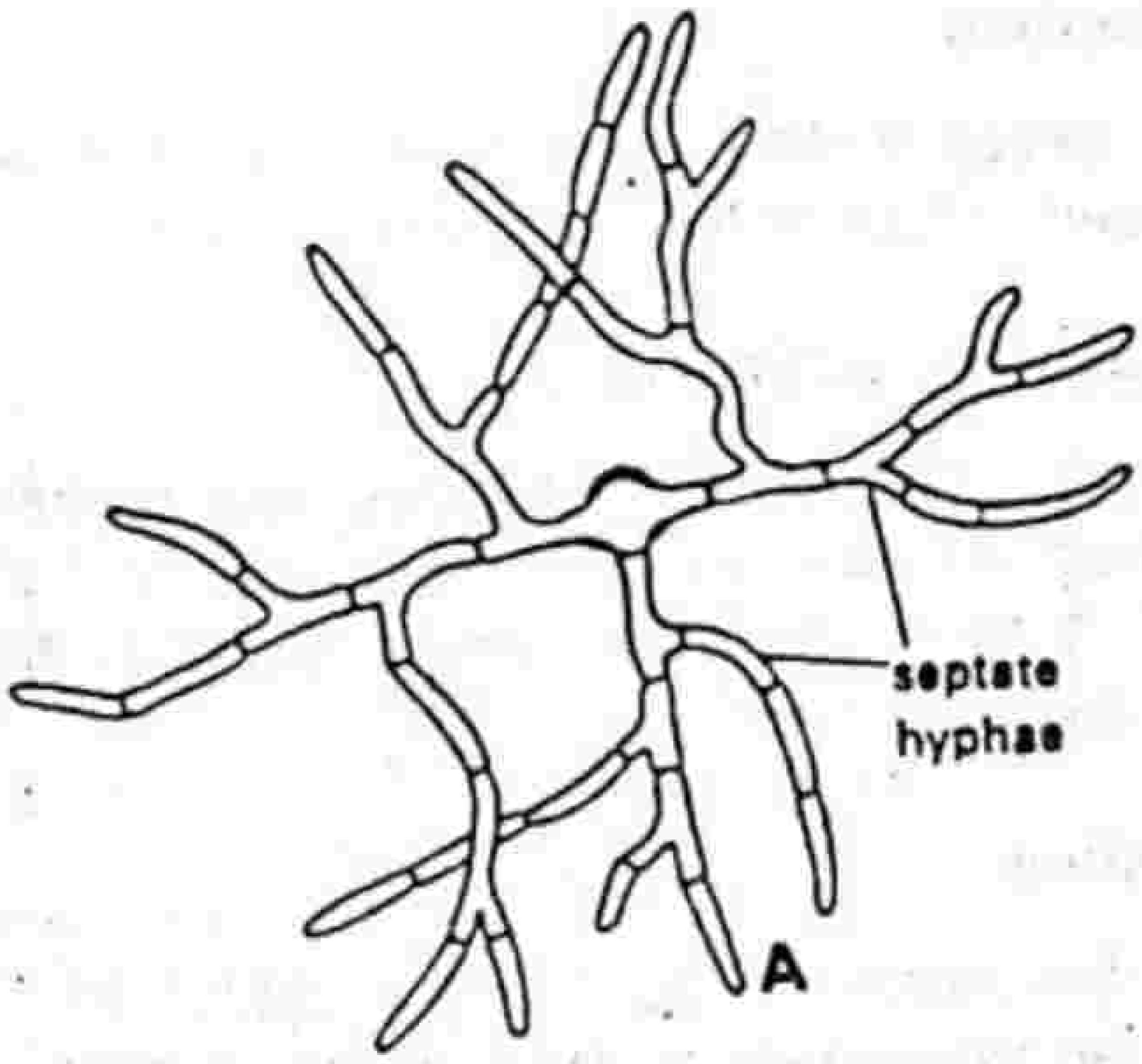
A well developed network formed of endoplasmic reticulum is present throughout the cytoplasm. It may be coated with ribosomes or without these.

Mitochondria

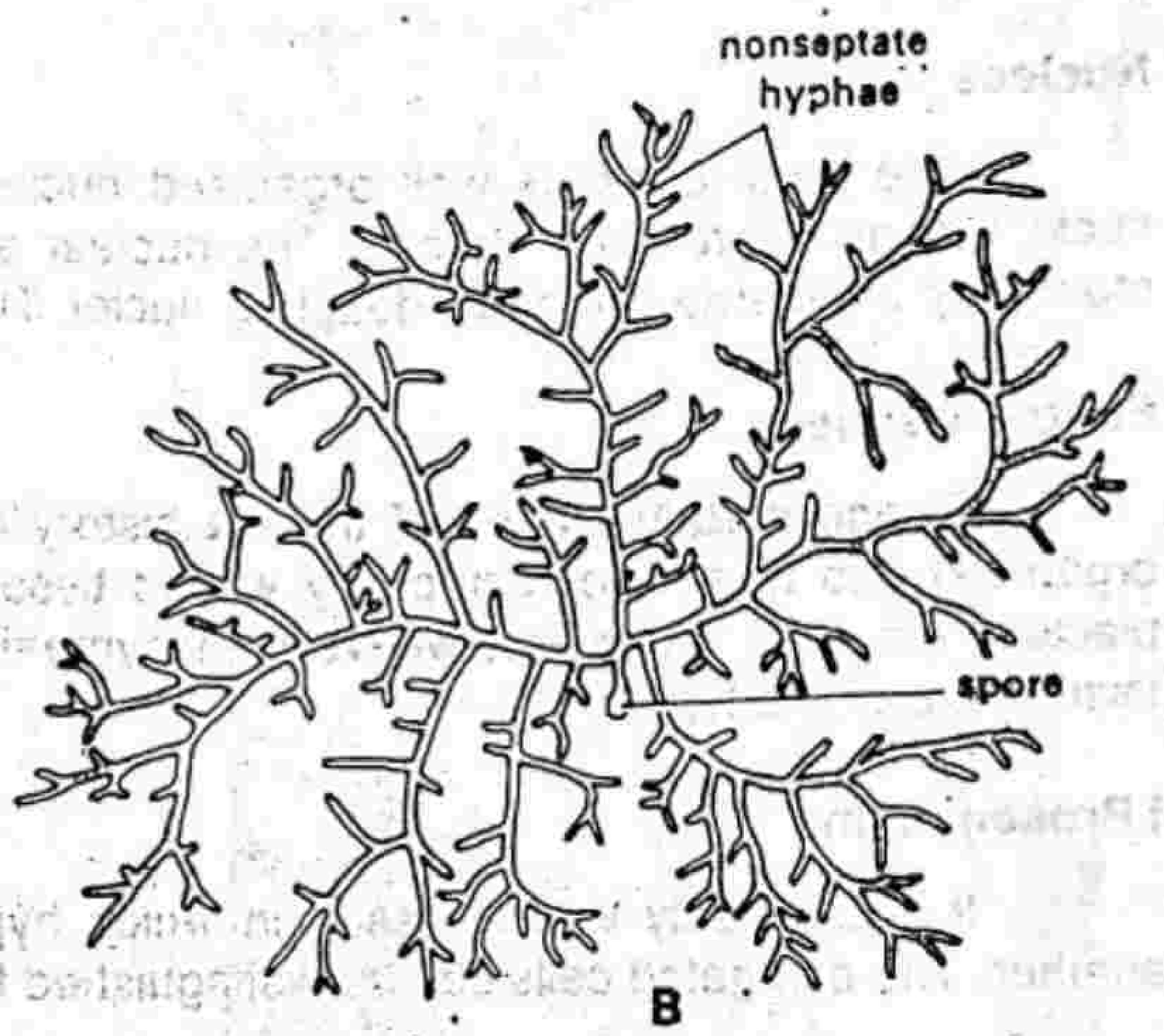
Mitochondria are found abundantly in hyphae. These are enveloped by double membrane. The outer membrane is being continuous with the endoplasmic reticulum.



A. Septate Hyphae; B. Aseptate Hyphae.



A Septate Mycelium



B, Non-septate Mycelium

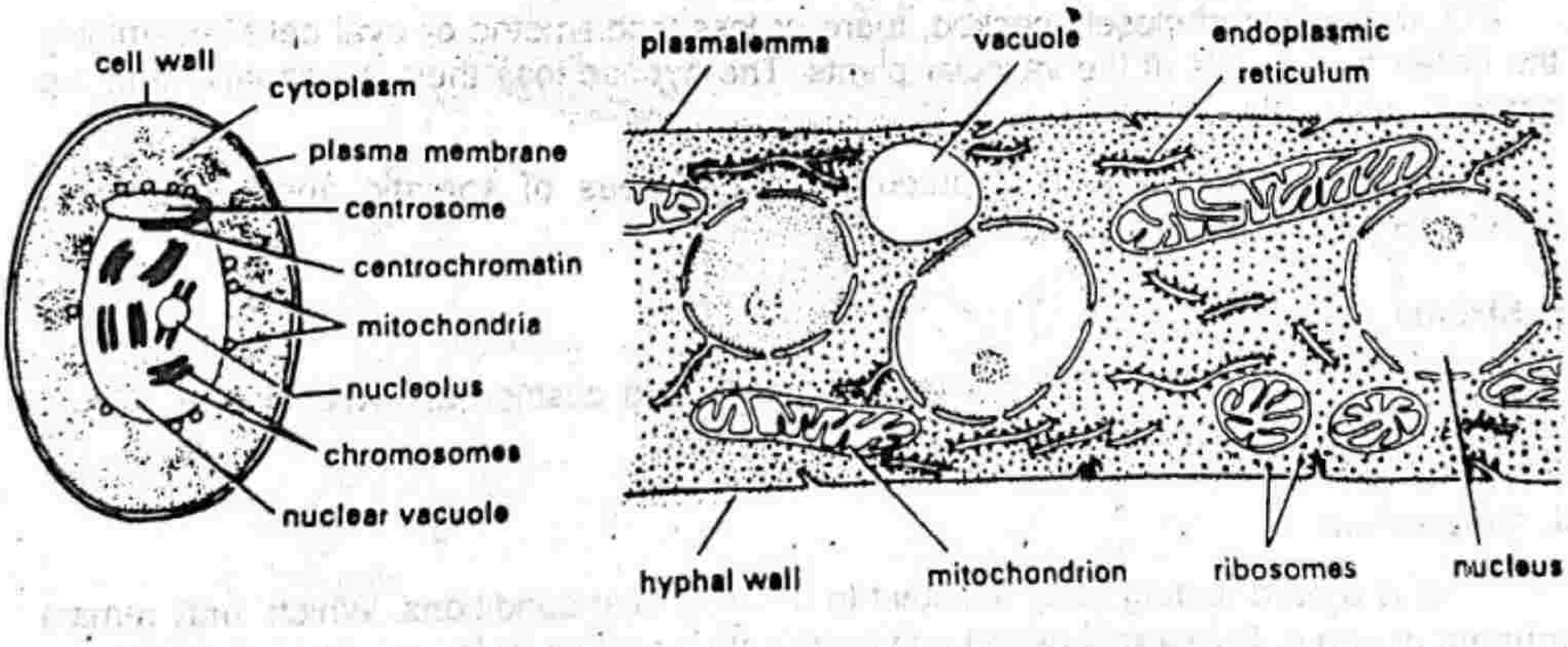


Fig. 5.1: Fungi — Vegetative morphology.

Golgi bodies

Golgi bodies have been reported rarely, however where present these are composed of four or five flattened cisternae.

Cytoplasmic microtubules

Cytoplasmic microtubules are present throughout the cytoplasm. These are concerned with cytoplasmic movement and maintenance of cell shape. Round or oval bodies called microbodies, which are considered to be the precursors of peroxisomes, occur frequently in fungi.

Ribosomes

Ribosomes occur freely in cytoplasm, or associated with endoplasmic reticulum. They may aggregate to form polyribosomes. These are concerned with synthesis of proteins.

Nucleus

The fungi possess well organized nucleus. It contains a nuclear envelope, a nucleolus, and chromatin strands. The nuclear envelope constricts in a dumb-bell like manner and separates into two daughter nuclei. The nucleolus consists mainly of RNA.

Fungal Tissues

During certain stages of the life history of most fungi, the mycelium becomes organized into loosely or compactly woven tissue. These are called fungal tissues or plectenchyma (Gr. plekein=to weave + enchyma=infusion __ a woven tissue). The fungal tissues are of two types

i.Prosenchyma

It is a loosely woven tissue in which hyphae lie more or less parallel to one another. The elongated cells can be distinguished from one another.

ii.Pseudoparenchyma

It consists of closely packed, more or less isodiametric or oval cells resembling the parenchyma cells of the vascular plants. The hyphae lose their individuality and are not distinguishable.

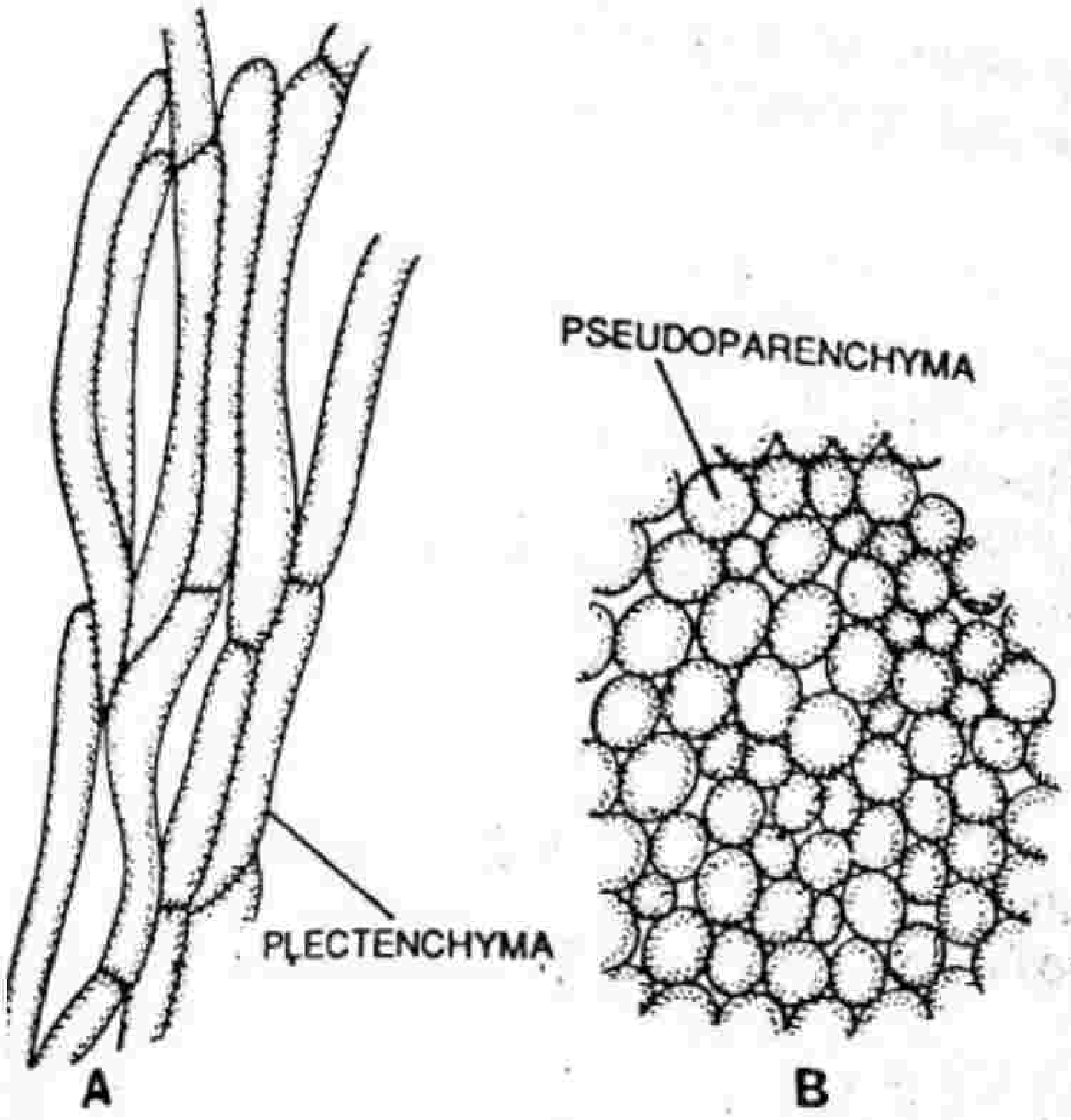
The fungal tissues also produce various types of somatic and reproductive structures in most fungi, such as:

i. Stroma:

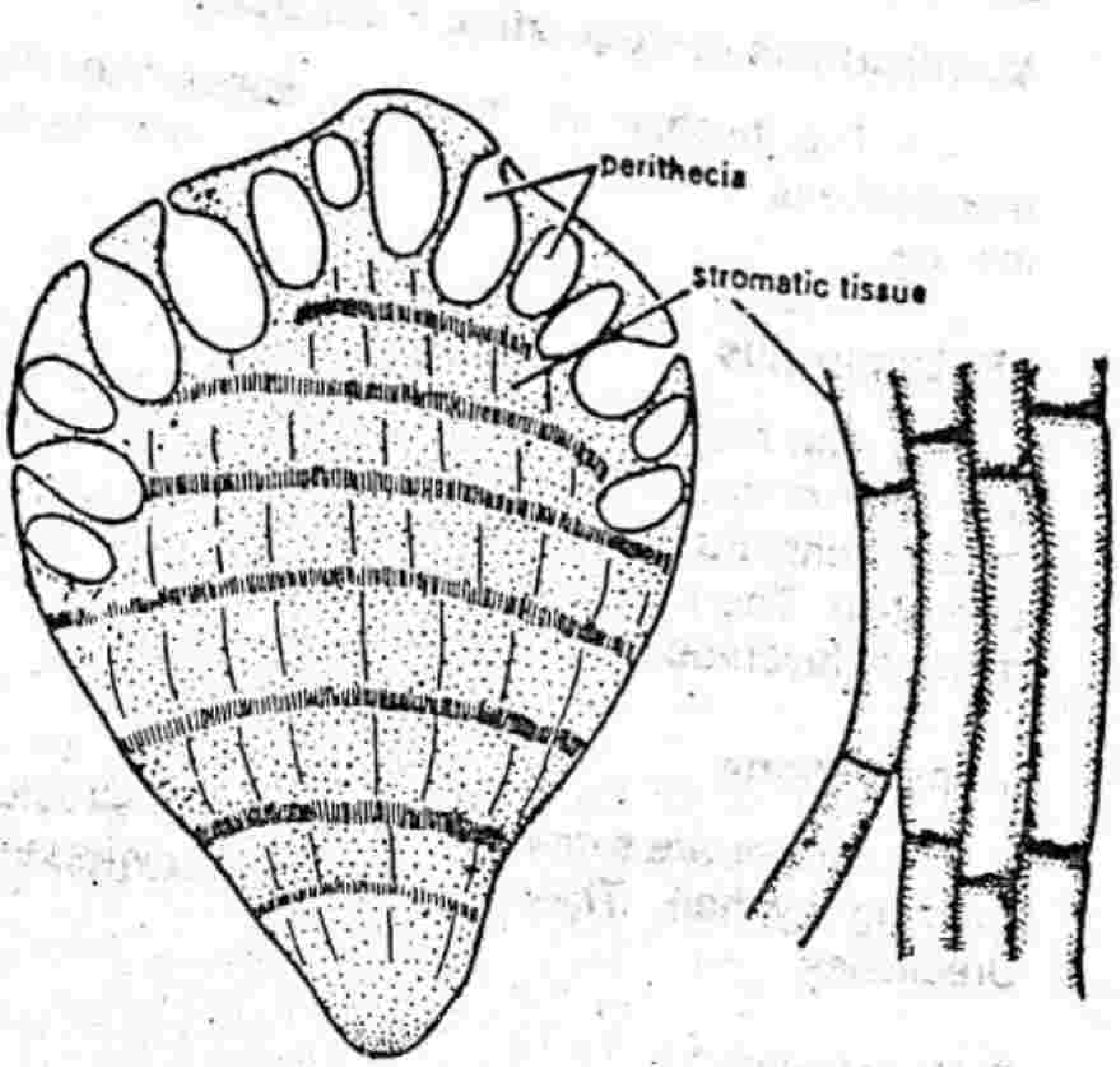
It is a compact, somatic structure much like a cushion on which fungal fruiting bodies are usually formed.

ii. Sclerotium:

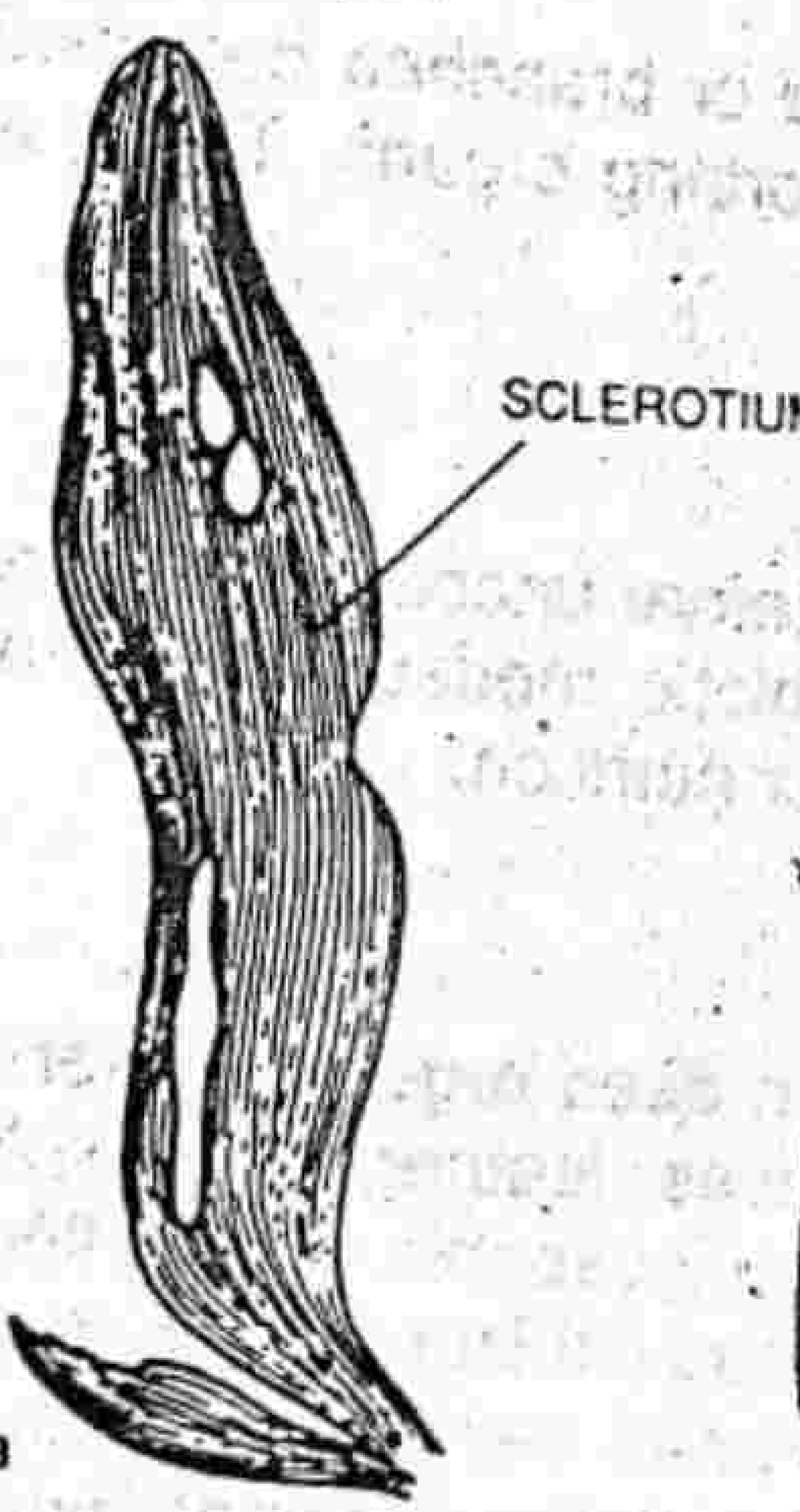
It is a hard resting body resistant to unfavourable conditions. Which may remain dormant during unfavourable period and germinate on return of favourable conditions.



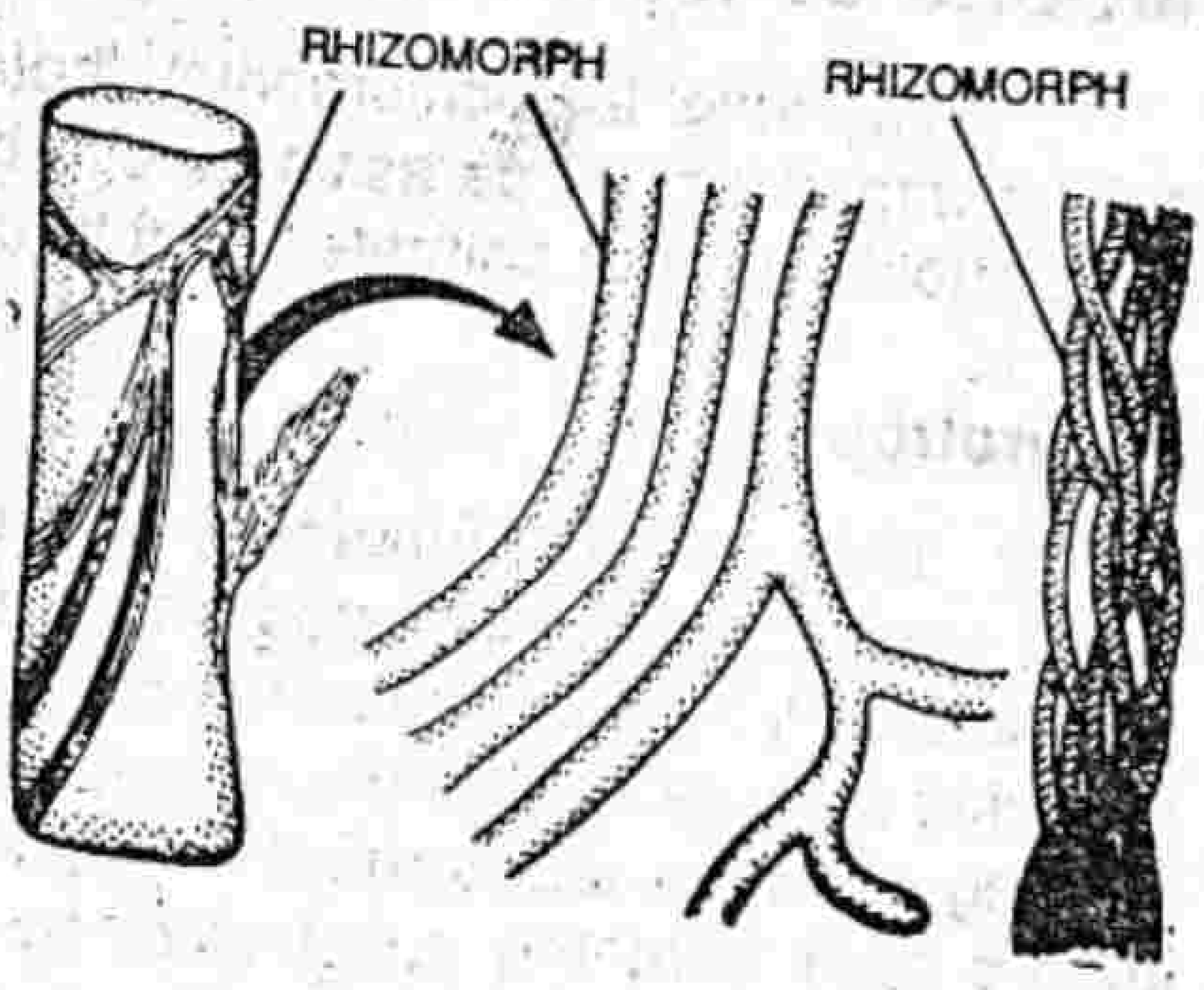
A. Plectenchyma; B. Pseudoparenchyma.

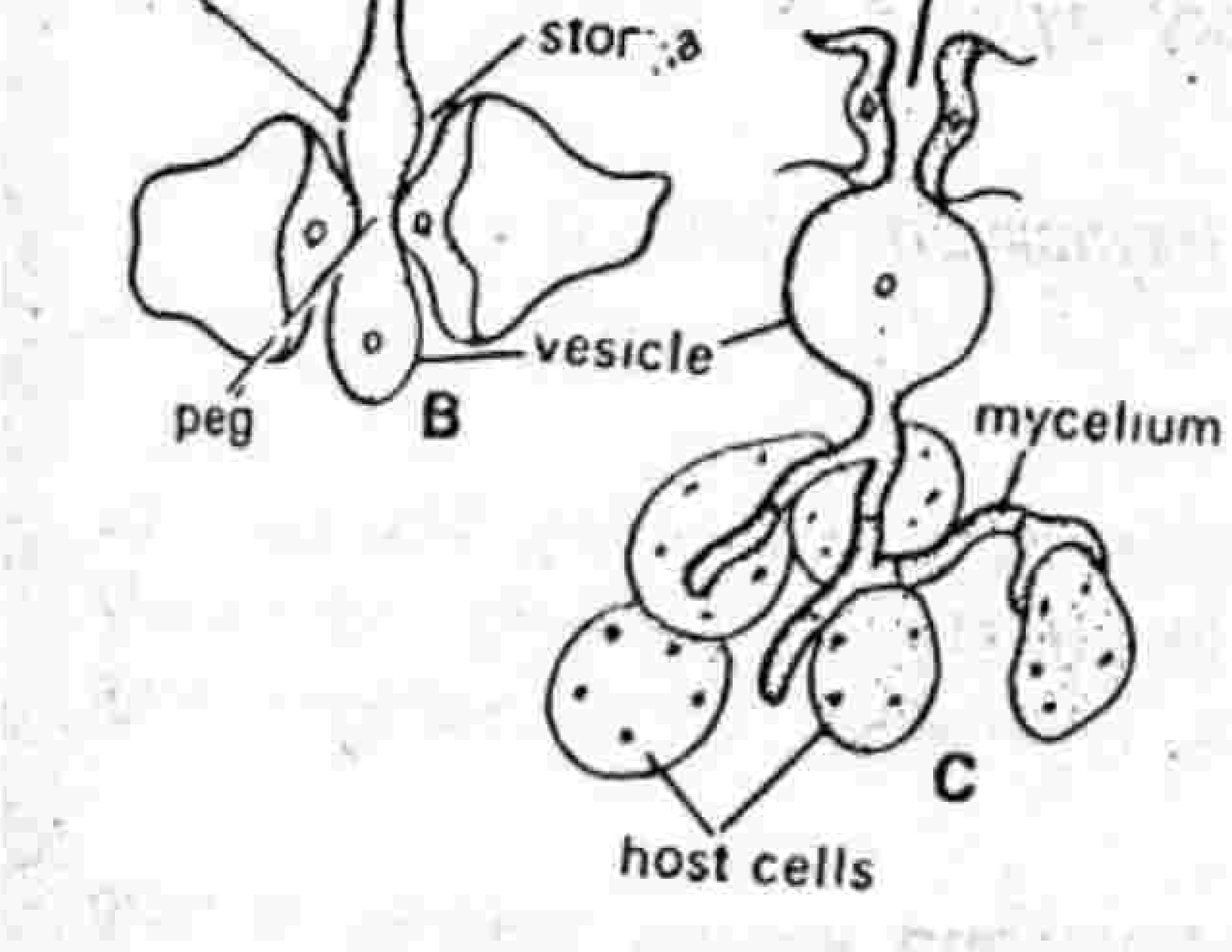


Stroma



Sclerotium.





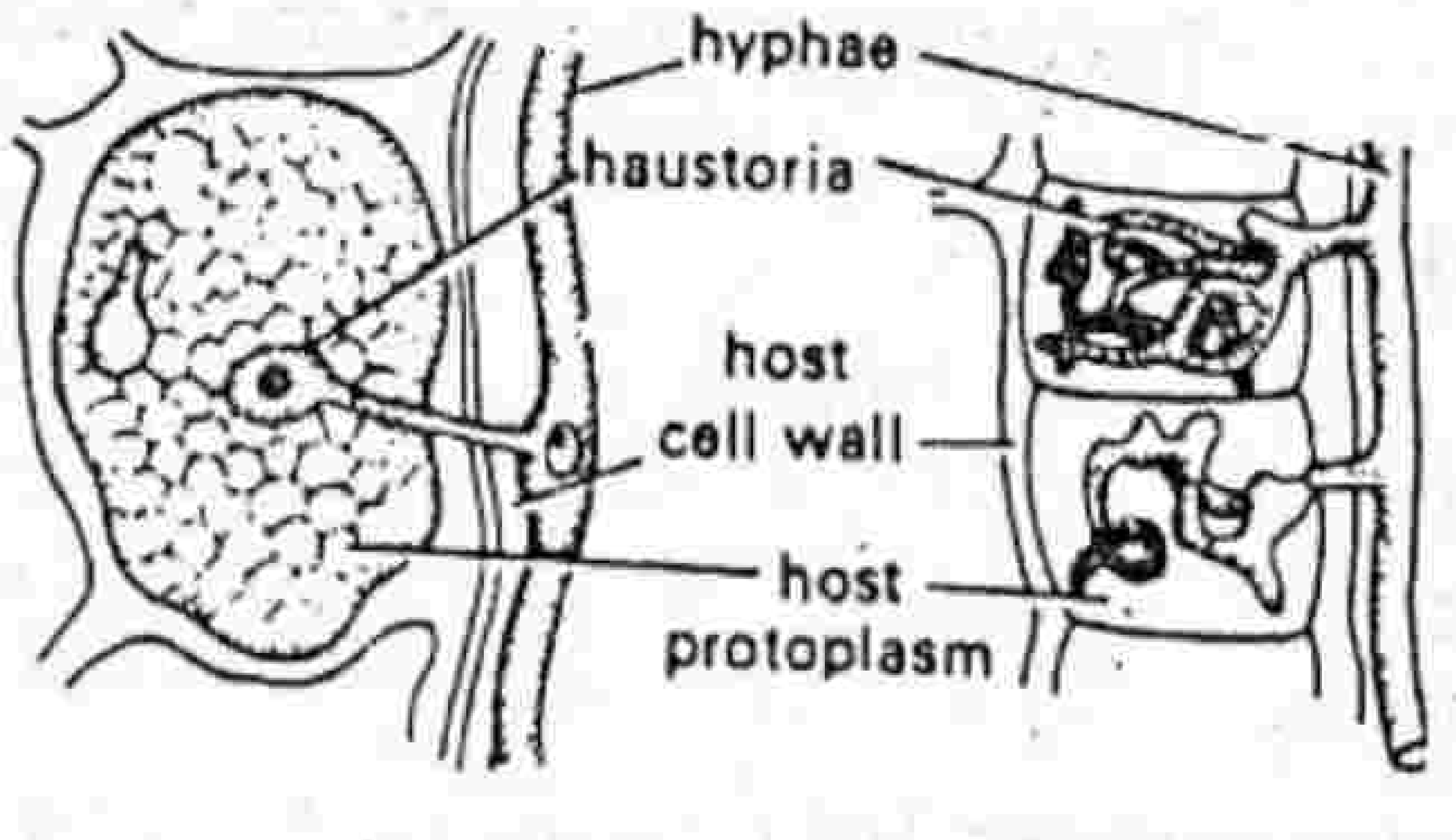


Fig. 5.2: Fungal tissues and hyphal modifications.

Modifications of Vegetative Plant Body

The hyphae or in some cases the mycelium of some fungi show certain modifications which enable them to perform certain characteristic functions. These include:

i.Rhizomorphs

The members of Basidiomycotina and some other groups which invade roots of the plants or destroy wood, the hyphae aggregate to form thick longitudinal strands called rhizomorphs. Each rhizomorph has a thick, hard cortex and a growing tip resembling that of root-tip. The rhizomorphs are resistant to adverse conditions and resume growth on return of favourable conditions.

ii.Appressoria

These are simple or lobed swollen structures that arise either from germ tubes or infecting hyphae. They are found in disease-causing fungi, e. g., in members of Uredinales.

iii.Haustoria

These are knob-like, elongated or branched outgrowths of the somatic hyphae. They are regarded as specialized absorbing organs. These are found in parasitic fungi such as *Albugo, Puccinia*, etc.

MODES OF NUTRITION

The fungi lack chlorophyll, therefore unable to manufacture their own food. They exhibit saprotrophic, parasitic or symbiotic modes of nutrition mostly. However, some fungi attack and trap animals to get their nutrition.

i.Saprotrophs

These are the fungi that live on dead organic matter. These are found on rotten fruits, vegetables; moist wood and leaves; leather; jams, jellies, pickles, cheese; horse and cattle dung; etc. Some of these are incapable of infecting living organisms to cause diseases and are called obligate saprobes (Rhizopus); whereas the others are capable of causing diseases and termed as facultative saprobes (Pythium). The saprotrophic fungi absorb food from the substratum by sending ordinary hyphae or by development of rhizoids into the substratum.

The common examples are *Mucor, Rhizopus, Penicillium,Agaricus*, etc.

ii.Parasites

These fungi live on a variety of living organisms called the hosts. The parasitic fungi absorb food material from the living tissue of the hosts. These fungi are usually harmful and cause many serious diseases in the hosts. The most common parasitic fungi include rusts, smuts, mildews, etc.

Ectoparasites: Their mycelium remains outside the host and absorb food by sending haustoria into the body of the host, e. g., Erysiphe.

Enodparasites, The mycelium is present inside the host.

iii.Symbionts

Some fungi form an association with other plants. Such a relationship is called symbiosis and the partners are called symbionts. The symbionts draw mutual benefits from each other.

a. **Lichens:**It is the symbiotic association of fungi with algae. The fungal partner provides shelter and absorb moisture whereas the algal partner synthesizes the food.

b. **Mycorrhizae:**In some cases, the fungi develop in the roots of higher plants to form mycorrhizae. These fungi help in absorption of moisturealong with minerals like phosphorous and in turn get food.

iv.Predacious Fungi

There are many fungi that trap small animals such as rotifers or protozoans. Such fungi are termed as predacious fungi. These fungi develop many animal trapping devices for capturing the animals. The examples are *Arthrobotrys, Dactylella and Dactylaria.*

REPRODUCTION

Generally vegetative, asexual and sexual modes of reproduction are recognized in fungi.

VEGETATIVE REPRODUCTION

The common methods of vegetative reproduction in fungi are:

i.Fragmentation

The body is divided into fragments. Each fragment grows into a new individual. This type of reproduction is found in most of the filamentous ascomycetes and basidiomycetes.

ii.Fission

The somatic cell splits into two daughter cells by formation of a constriction or a transverse wall. The nuclear division is mitotic. This type of vegetative reproduction is found in yeast.

iii.Budding

In this method a small outgrowth called bud is produced. The nucleus of the parent cell divides and one of the daughter nucleus migrates into the bud. The bud is separated from the parental cell by the formation of a septum. The buds separate from the parental cell and become an independent individual. The budding is common in yeasts (Saccharomyces). In some cases the buds do not separate and form chains of cells called pseudomycelium.

iv.Sclerotia and Rhizomorphs

These are modifications of hyphae which are resistant to the unfavourable conditions and may remain dormant for longer periods and germinate on the return of favourable conditions.

ASEXUAL REPRODUCTION

The most common method of asexual reproduction in fungi is by means of asexual spores. Asexual reproduction occurs normally under conditions that favour growth and several generations may be produced in one season.

Following are the various methods of asexual reproduction in fungi

1. Arthrospore

The hyphae break up into their component cells that behave as spores. These spores are called as athrospores.

2. Chlamydospores

If the cell become enveloped into wall before their seperation from each other they are called as chlamadospores.

3. Spores

When the spores are produced inside the sporangium then it is called as spores. The spore bearing branch is called as sporangiospore.

4. Conidia

If the spore like structure produced externally in the form of chain then it is called as conidia. Theconidia bearing branch is called as conidiophore.

5. Zoospores

The motile spores are called as zoopores. They use flagella for their motility.

6. Aplanospores

The non-motile spores are called as aplanospores.

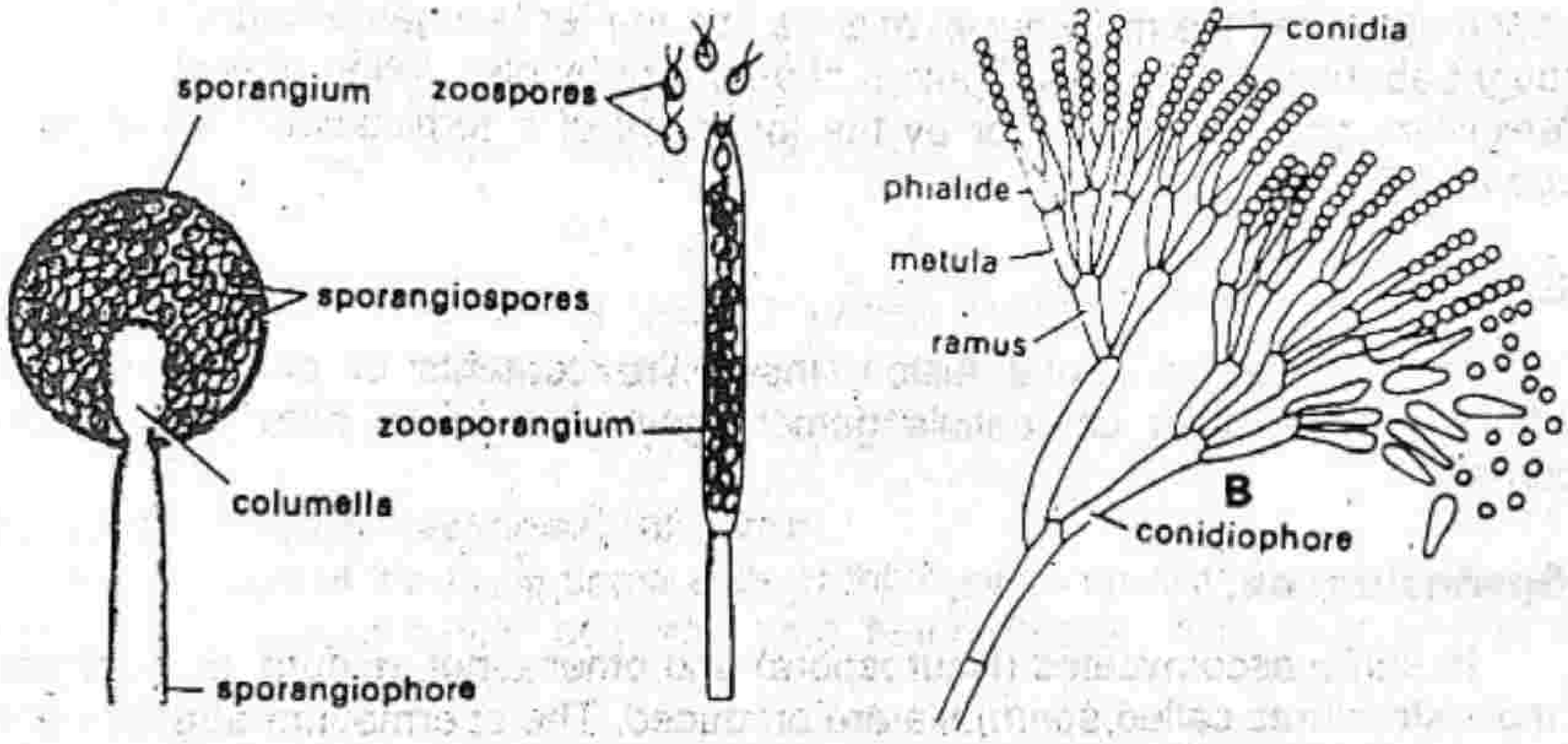


Fig. 5.3: Asexual reproduction

SEXUAL REPRODUCTION

The sexual reproduction in fungi involves fusion of two compatible nuclei. The process of sexual reproduction consists of three distinct phases:

Plasmogamy

Plasmogamy involves the fusion of protoplasts to bring the nuclei together.

Karyogamy

Karyogamy involves the fusion of the nuclei followed by meiosis which restores the haploidy.

Sex Organs

The fungal sex organs are called the gametangia. These may be similar morphologically (isogametangia) or differ from each other (heterogametangia). In later case, the male gametangium is called an antheridium (pl. antheridia) and the female gametangium is called the oogonium (pl. oogonia). The male gametes are termed antherozoids and female gametes, the eggs.

Methods of Sexual Reproduction

The compatible nuclei are brought together by any one of the following methods during sexual reproduction. These methods are often referred to as methods of sexual reproduction.

i. Planogametic Copulation:

This type of sexual fusion involves fusion of two naked gametes. Both or one of these gametes may be motile (planogamete). For example, in *Plasmodiophora*.

ii. Gametangial Contact:

In this type of sexual fusion the two gametangia of opposite sex come in contact with each other and the male nuclei migrate into the female gametangium. This migration is brought about either by development of a pore or by dissolution of wall of contact, e. g. in *Penicillium and Aspergillus*, or by the formation of a fertilization-tube as in *Pythium, Albugo and Peronospora*.

iii. Gametangial Copulation:

In this type of sexual fusion, the entire contents of one gametangium are transferred to the other compatible gametangium through a pore, e.g., in *Rhizopus, Mucor*, etc.

iv. Spermatization:

In some ascomycetes (Neurospora) and other fungi, minute, uninucleate, spore-like male structures called spermatia are produced. The spermatium attaches itself to the trichogyne of female and the wall of contact between the two dissolves. The male nucleus migrates into the female gametangium and fuses with the female nucleus to form the zygote nucleus. This type of sexual fusion is called spermatization.

v. Somatogamy:

In some fungi, e. g., in Morchella the sex organs are not produced and the sexual fusion is brought about by the fusion of two somatic hyphae of different species. This type of sexual fusion is called somatogamy.

Parasexuality

Some fungi do not go through a true sexual cycle but derive benefits of sexuality through parasexuality (Gr. para=beside + sex). During this process plasmogamy, karyogamy and haplodization takes place, as in a true sexual cycle, but not at specified time or at specified points during the life cycle. The parasexual cycles are found in Deuteromycotina (in which the sexual reproduction is absent).

The sequence of events involved in a complete parasexual cycle include:

i. The formation of a heterokaryotic mycelium by somatic hyphae of different genetic constitutions followed by the division of foreign nucleus and spread of daughter nuclei through the mycelium.

ii. **Karyogamy:** It is the fusion between haploid nuclei of different genotypes as well as between nuclei of the same type, resulting in heterozygous and homozygous diploid nuclei.

iii. The multiplication of diploid nuclei side by side with the haploid nuclei.

iv. Mitotic crossing over of diploid nuclei takes place during multiplication. It would results in new combinations and new linkages.

iv. Formation ofconidia takes place which germinate and produce diploid mycelia.

v. Some diploid nuclei undergo haplodization and produce haploid conidia.

LIFE CYCLE

The fungi also exhibit a cycle of haploid and diploid structures corresponding to the gametophytes and sporophytes in the green plants.Raper (1954, 1966) recognized seven basic types of life cycles in fungi. These are:-

i.Asexual Cycle

In this type of life cycle the sexual reproduction is apparently absent and the diploidy is restricted to the somatic structures. All fungi imperfecti and some other species like *Penicillium notatum* show this type of life cycle.

ii.Haploid Cycle

This is the simplest life cycle in which the meiosis follows nuclear fusion immediately. The diploid phase is confined to the zygote only. This type of life cycle is found in many lower fungi and some Ascomycetes.

iii.Haploid Cycle with Restricted Dikaryon

In this type of life cycle some cells of the hyphae contain paired nuclei lying side by side. These nuclei divide at same time before fusion. This type of life cycle is characteristics of ascomycetes.

iv.Haploid Dikaryotic Cycle

In this type of life cycle the mycelium develops from a meiospore and is a monokaryon. But after dikaryotization the mycelium shows an unrestricted and independent growth and may form the longest phase of the life cycle. This type of life cycle is characteristics of basidiomycetes except many Ustilaginales.

v.Dikaryotic Cycle

In this type of life cycle the meiospores fuse immediately to form a dikaryon. This dikaryotic phase persists throughout the life cycle of fungus usually, e. g., in yeasts and smuts.

vi.Haploid-Diploid Cycle

During this life cycle the haploid and diploid phases alternate regularly. This life cycle is of rare occurrence in fungi and is described in Blastocladiales (order of Chytridiomycetes) and Endomycetales.

vii.Diploid Cycle

In this type of life cycle the haploid phase is represented by gametes only. It is known in majority of Oomycetes, Yeasts, Myxomycetes and in some members of Blastocladiales.

ORIGIN AND PHYLOGENY OF FUNGI

The origin and evolutionary relationship (phylogeny) of fungi are not definitely known. However, two main schools of thought exist regarding the origin of the fungi. One group advocates the origin of fungi from algae, whereas the other group suggests the origin of fungi from protozoa.

Algal Hypothesis

The proponents of algal hypothesis suggest that fungi have been derived from algae by loss of chlorophyll. The believers of algal hypothesis are further divided into two camps. Those who believes in monophyletic origin hold that with the exception of slime molds and simple fungi all others groups represent one main evolutionary line of fungi evolved from a common algal ancestor. The others believe in polyphyletic origin and suggest that fungi are a heterogeneous aggregation originated from various groups of algae. For example, the phycomycetes are considered to be evolved from either Chlorophyta or Xanthophyta, Ascomycotina and Basidiomycotina from the Rhodophyta.

Protozoan Ancestory of Fungi

There are quite a number of mycologists who believe that the fungi arose from the protozoa. Gobi (1884) adopted and supported by a number of workers. Some workers favour monophyletic while others polyphyletic origin, but all agree that derivation of fungi from algae present more difficulties than does a theory of protozoan origin.Inspite of resemblance of fungi with plants in cellular structure of their thalli and their reproduction by spores, mycologists now believe that most fungi have originated from some protozoan-like flagellate.

ECONOMIC IMPORTANCE OF FUNGI

Fungi exhibits both beneficial and harmful effects in our daily life. Both these are important economically as followings.

BENEFICIAL ROLES OF FUNGI

Fungi exhibits the following beneficial roles:

i.Fungi as Decomposing Agent

Fungi alongwith bacteria are responsible for disintegration of organic matter causing decay of dead plants and animals resulting in formation of humus and nutrient recycling. Important nutritional elements such as nitrogen, phosphorus, potassium, sulphur, iron, calcium etcare released which are utilized by plants. Carbon dioxide is also liberated to the atmosphere during decomposition which is used by green plants.

ii.Industrial Use of Fungi

Fungi play important role in various industrial processes such as:

a. The yeasts are the basis of baking and brewing industries,

b. Fungal spp. are used in manufacture of certain types of cheese

c. Another industrial use of the fungi is in manufacture of citric acid (*Aspergillus niger*), the basis of enormous soft drink industry. Similarly fumaric acid and lactic acid are obtained from fungal species (*Rhizopus stolonifer*).

iii.Source of Antibiotics

A very important and vital role of fungi is its usage in production of antibiotics, notably penicillin and griseoflavin, in manufacture of vitamins such as riboflavin, and of various important drugs such as ergotamine and cortisone.

iv.Fungi as Food

The mushrooms play a great role in human affairs. These are rich source of proteins and vitamins and are widely used as food for their excellent flavour and food values. Some mushrooms are deadly poisonous and are called toadstools. Therefore, one should be careful in selecting mushrooms and should always rely on farm products as there are no methods for distinguishing edible and poisonous mushrooms in case of naturally growing mushrooms.

The protein contents of yeasts are estimated to be more than 40%, therefore these are largely used as food. *Saccharomyces cerevisiae* is universally used for the production of yeast cake.

v.Source of Enzymes, Hormones and Vitamins

Many fungal species are a good source of enzymes like amylase (*Aspergillus sp*), invertase (yeast), pectinase (*Penicillium sp*). Therefore, these species are used for commercial production of enzymes.

Similarly fungi are an important source of hormones, for example Gibberella fujikuroi is a source of gibberellins, a group of plant hormones. Similarly Mucor sp is a source of trisporic acid.

Saccharomyces cerevisiae and other yeasts are good sources of vitamin B-complex and riboflavin. Also ergosterol which contains vitamin-D is produced by yeast and mold species.

vi.Fungi as Research Tool

Cytologists, geneticists and biochemists have found fungi an important research tool in the study of fundamental biological processes. The fungi show a faster rate of growth and a large number of generations can be grown in a limited time period. Further, because the spores are produced as a result of meiosis and these germinate to produce a haploid generation, a direct and rapid analysis of tetrads can be made. Also the fungi can be grown in test tubes, require a little space, less care, and less expensive equipment, therefore, these are the best choice as research tools.

Red bread mold *Neurospora* has proved an ideal organism for study of laws of heredity, genic control of enzymes and helped in laying the foundations of a new branch of science known as haploid genetics. The slime molds have also been widely used in research.

vii.Fungi as Symbionts

Fungi exhibit a good symbiotic relationship with the green plants. These are main partners of lichens, an association of fungi and algae, where these provide shelter and absorb moisture for the algal components. Also these infect roots of many higher plants to form a symbiotic mycorrhizal system that helps in absorption and retention of moisture

viii.Fungi as Insecticide

Many fungi attack a number of insects that are harmful to crops. Most of the insect-attacking fungi belong to the order phycomycetes or deuteromycetes. Beauveria bassiana and Metarrhizium anisopliae are used to control insect-pests since long. Coelomyces, an aquatic fungus, attacks mosquito larvae and kill them. Thus by attacking and killing the harmful insects the fungi indirectly plays a very important role in the betterment of economy and also in controlling dreadful disease like malaria.

Harmful Aspects of Fungi

The harmful aspects of fungi are:

i.Role as Pathogens

The fungi cause diseases in plants and animals including the human beings.

a. **Diseases in Plants:**The fungi are destructive to agriculture and are responsible for damages worth millions of rupees to crops by causing plant diseases. The majority of plant diseases are caused by parasitic fungi. Most common fungal diseases are rusts and smuts of cereals, mildews of fruits, rots (red rot of sugar-cane), wilts (wilt of cotton), damping off, potato blight, ergot of rye, etc.

Fungal diseases may lead to catastrophe if go unchecked, for example *Phytophthora infestans* caused a disastrous effect on potato crop in Ireland during 1845-49, causing a feminine. About one million persons died of this famine.

b. **Diseases in Animals:**The fungal diseases are also common in animals. Trichophyton and Microsporum spp have been reported to cause ringworms in dogs and horses; and mycotic abortions in cattle. Similarly *Aspergillus fumigatus* causes bovine abortion in many animals including ducks, chickens and other birds.

c. **Diseases in Humans:**The fungi cause infections in almost all the body parts of the human beings, however fungal infections involve skin. *Rhizopus* and *Mucor* species are common fungal pathogens that cause infections in lungs, brain and gastric tissues. Histoplasm is responsible for the infection of the lungs, spleen, liver, kidney, nervous and lymphatic systems. Aspergillosis, whose symptoms closely resemble those of tuberculosis is caused by *Aspergillus* spp. Most of the fungi are skin infestants. These include *Trichophyton* and *Candida* spp.

ii.Role in Spoiling Food and stored Grains

The food articles, if not properly stored, are attacked and spoiled by fungi. The common food spoiling fungi are *Aspergillus, Rhizopus,Mucor* and *Penicillium*. Some deuteromycetes contaminate stored grains like wheat and maize.

iii.Production of Toxins

Some basidiomycetes like *Amanita phalloides* (death cup), *Amanita verna* (destroying angel) and *Boleus satanus* are highly poisonous. These fungi produce toxins that destroy the plasma membrane of the liver cells, cause lesions in stomach and intestine cells and affect kidney and liver. *Aspergillus flavus* produces a carcinogenic toxin aflatoxin which is known to induce cancer in poultry and humans especially that of liver. *Claviceps purpurea*, an ascomycetous fungus, causes ergot disease of rye. The sclerotia of this fungus contains poisonous alkaloids like ergotamine and ergo-cystinine.

iv.Production of Hallucinogenic Drugs

Some agaricales like *Psilocybe mexicana, Amanita muscaria* have hallucinogenic properties (illusion of seeing or hearing something that is not there). In *Psilocybe mexicana* this property is due to presence of two compounds, the psilocybin and psilocin. Psilocybin resembles lysergic acid from which famous psychoactive drug LSD (lysergic acid diethylamide) is derived. Ingestion of *Amanita muscaria* results in trembling of limbs within an hour, excitation and euphoria, and the person becomes unconscious. The initial symptoms are caused by the presence of two alkaloids, muscarine and bifotenine and damage to the central nervous system is caused by muscimol.

v.Role in Wood Rotting

Many fungi act as wood rotting agents and cause a lot of monetary loss. Two major types of wood rots are dry rot and wet rot of timber (wood used for construction purposes). The dry rot is caused by *Serpula lacrymans* and the wet rot by *Coniophora* cerebella. These fungi break down the wood components and reduce its mechanical strength.

CLASSIFICATION OF FUNGI

Linnaues was first to recognize and classify fungi as 24th class of his system of classification, the Cryptogamia. The fungi was placed in Thallophyta alongwith algae due to presence of three common characters:

1. The plant body a thallus.
2. The sex organs usually unicellular and when multicellular all the cells are fertile.
3. The zygote does not develop into a multicellular embryo while it is still attached to the female reproductive organ.

At that time it was believed that the fungi are evolved from the algae by loss of chlorophyll but the present consensus is that fungi evolved from protozoan-like ancestors. The physiology and cell wall composition of fungal cell is entirely different from that of algae. Therefore, it is not proper to keep the fungi alongwith algae in the same group.

Ainsworth's system is considered to be most ideal scheme of classification as it reflects natural relationship among the members of the groups. John Webster (1980) also followed Ainsworth's system of classification. This system of classification is followed in the book.

Criteria for Classification

The criteria for classification used in most systems of classifications are:

i. The nature of somatic phase whether unicellular or a mycelium and if a mycelium whether septate or aseptate.
ii. The kind of sexual spores, sporangiospores or conidia. Their number, presence or absence of organs of locomotion, the flagella, and if present form and arrangement of flagella.
iii. The kind of sporangia.
iv. The nature of the life cycle whether asexual, haplontic, diplontic, haplodiplontic or haploid-dikaryotic types.
v. The presence or absence of the perfect or sexual stage.
vi. Dyal (1975) mentioned following seven characters as the basis of fungal classification. These include: morphological characters, host specialization, physiological characters, cytological and genetical characters, serological characters, biochemical characters, and numerical taxonomy.

Nomenclature

In accordance with the recommendations of the committee on International Rules of Botanical Nomenclature, which is accepted by the mycologists, the following suffixes should be used to denote various categories of fungi.

i. Divisions should end in *-mycota*.
ii. Sub-divisions in *-mycotina*.
iii. Classes in *-mycetes*.
iv. Sub-classes in *-mycetidae*.
v. Orders in *-ales*.
vi. Families in *-aceae*.
vi. Genera (sing. genus; L. genus=race) and species (L. species=concept) have no standard endings.

AN OUTLINE OF AINSWORTH SYSTEM OF CLASSIFICATION

An outline of Ainsworth system of classification is as follows:

Kingdom:FUNGI

The kingdom is divided into two divisions.

Division I: Myxomycota

The division includes slime molds. It is further classified into four classes.

Class 1: Acrasiomycetes: It includes the slime molds in which the free living assimilatory phase is amoebae which unite as a pseudoplasmodium before reproduction.

Class 2: Labyrinthulales: This class includes net-plasmodium, the assimilative phase being plasmodium.

Class 3: Myxomycetes: This class is characterized by the presence of free-living saprobic plasmodium.

Class 4: Plasmodiophoromycetes: In this class parasitic plasmodia present within the host cells are included.

Division II: Eumycota

The division includes true fungi characterized by the presence of mycelium. The division is further classified into five sub-divisions.

Sub-division A: Mastigomycotina

The fungi which reproduce asexually by the formation of zoospores and sexually by oospores are included in this sub-division. The sub-division is divided into three classes.

Class 1: Chytridiomycetes: The zoospores are uniflagellate. The flagellum is posteriorly inserted and is of whiplash type.

Class 2: Hyphochytridiomycetes: The zoospores are uniflagellate but the flagellum is anteriorly inserted and is of tinsel type.

Class 3: Oomycetes: The zoospores biflagellate, one posteriorly and the other anteriorly inserted. The posterior one is of whiplash and anterior one is tinsel type. The cell wall is cellulosic.

Sub-division B: Zygomycotina

The sub-division includes the fungi in which the asexual reproduction by zoospores is absent. The sexual spores are zygospores. The sub-division is divided into two classes.

Class 1: Zygomycetes: Most of the fungi present in this class are saprobic. But parasitic or predacious forms are also found with their mycelia immersed in the host tissue.

Class 2: **Trichomycetes:**This class includes those fungi that are attached to the cuticle or the digestive tract of the arthropods by a holdfast and the mycelium is not immersed in the host tissue.

Sub-division C: Ascomycotina

The sub-division include those fungi in which zoospores and zygospores both are absent and the perfect state (sexual state) spores are ascospores. The sub-division is divided into six classes.

Class 1: **Hemiascomyctes:**The fungi included in this class has mycelial or yeast-like thallus. The ascogenous hyphae and the ascocarp formation is absent.

Class 2: **Loculoascomycetes:**The fungi in which the thallus is mycelial, and ascogenous hyphae and ascocarp formation is present, are included in this class. The asci are bitunicate and the ascocarp is an ascostroma.

Class 3: **Plectomycetes:**The fungi included in this class also have mycelial thalli and formation of ascogenous hyphae and ascocarp take place. But the asci are unitunicate and the ascocarp is a cleistothecium. The ascospores are aseptate.

Class 4: **Laboulbeniomycetes:**The fungi placed in this class are exoparasites of arthropods. The ascocarp is a perithecium with asci arranged in the form of a basal or peripheral layer within the perithecium. The asci are inoperculate.

Class 5: **Pyrenomycetes:**The fungi belonging to this class have perithecium type ascocarps. The asci are inoperculate and open through an apical pore or slit.

Class 6: **Discomycetes:**The members included in this class have apothecium type ascocarps that may be epigean or hypogean. The asci may be inoperculate or operculate.

Sub-division D: Basidiomyctoina

The members of the sub-division are characterized by absence of zoospores and zygospores. The sexual spores are basidiospores. The sub-division is further divided into three classes.

Class 1: **Teliomycetes:**The fungi included in this class are parasitic on vascular plants. The basidiocarps are absent and are replaced by teliospores or chlamydospores which are grouped in sori or scattered within the host tissue.

Class 2: **Hymenomycetes:**The fungi found in this class are mostly saprobes, rarely parasites. The basidiocarps are present and these may be gymnocarpous or semi-angiocarpous. Basidia are organized in the form of a hymenium. The basidiospores are ballistospores.

Class 3: **Gasteromycetes:**The members of this class are mostly saprophytes, and possess well developed basidiocarps which are typically angiocarpous. The basidiospores are not ballistospores.

Sub-division E: Deuteromycotina

The members of this sub-division are characterized by the absence of zoospores as well as perfect state spores, the ascospores and basidiospores. The spores found are conidiospores. The sub-division is divided into three classes.

Class 1: **Blastomycetes:**The fungi included in this class lack true mycelium, or if present a poorly developed one. Budding cells with or without pseudomycelium characteristic are present.

Class 2: **Hyphomycetes:**The fungi classified in this class possess a well developed true mycelium. The mycelium may be sterile or bear spores directly on special branches, the sporophores. Pycnidia or acervuli are absent.

Class 3: **Coelomycetes:**The fungi included in this class have well developed mycelium and the spores are produced in pycnidia or acervuli.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Define fungi.
2. Give difference between hypae and mycelium.
3. What is stroma in fungi.
4. What is apresorium.
5. Define mycorhizae.
6. What are arthospores.
7. Give difference between conidia and spore.
8. What is gametaqngia contact.
9. What is algal hypothesis for the origin of fungi.
10. What is the importance of fungi as food.
11. Enlist diseases of fungi.
12. What is the basis of fungal classification.
13. What are myxomycota and eumycota.

B. Long Questions

1. Describe types of asexual reproduction in fungi.
2. How many types of fungal tissues you have studied.
3. Describe mode of nutrition in fungi.
4. Describe life cycle of fungi.
5. Describe economic importance of fungi.
6. What is role of fungi in industry.

MYXOMYCOTA

SLIME MOLDS

1. The organisms included in the division are commonly termed as slime molds (slime thick, soft, slippery liquid substance, especially mud).
2. The somatic phase is plasmodiuma free-living creeping, multinucleate mass of Protoplasm usually enveloped by a slime sheath that totally lacks cell wall.
3. The whole mass is converted into one or more fruiting bodies, which bear spores.
4. Slime molds differ from true fungi in that they lack cell wall and protoplast is surrounded by plasma membrane, their feeding phase resembles an amoeba and they exhibit phagotrophic nutrition (ingestion of solid particles).

Ainsworthplaced the smile molds in a division, the Myxomycota and divided it into four classes as followings.

a. **Acrasiomycetes:** The assimilative phase is free-living amoebae that unite to form a pseudo plasmodium before reproduction.
b. **Hydromyxomycetes:** The assimilative phase is a plasmodium and the plasmodia form a network (net plasmodium).
c. **Myxomycetes:** The assimilative phase is a plasmodium that is free living but saprobic.
d. **Plasmodiophoromycetes:** The assimilative phase is a plasmodium. Most are endoparasites. i.e., live within the host cells.

PLASMODIOPHOROMYCETES

1. The class include endoparastic slime molds. Most of the members are obligate parasites of algae, fungi andhigher plants (usually found in roots). These cause enlargement and abnormal cell division (hypertrophy and hyperlapsia) of the host cells.
2. The somatic phase is a holocarphic plasmodium that develops inside the host cell.
3. The plasmodia may be sporogenus plasmodiain which the sporangia aggregate to form, loose masses or sori and biflagellate zoospores develop inside the sporangia or cystogeous plasmodiain which the zoospores fuse before infecting the host but karyogamy is delayed. The resultant plasmodium produces thick-walled resting spores called cysts.Each cyst produces primary zoospores or myxoameobea upon germination.
4. A unique feature of this group is a specific type of nuclear division called cruciform division or promitosis.During this division the nucleus elongates and becomes dumb-bell-shaped and the chromosomes arrange themselves around it in the form of a ring at metaphase. This configuration resembles a cross, therefore bained cruciform division. Shortly after the cruciform division is over the nucleus disappears as little or no chromatin can be seen. This stage is called akaryote phase.
5. The common genera of the class are *Plasmodiophora brassica*, a parasite of Brassica sp, and *Spongospora subterranean* that causes. Powdery scab of potatoes. The class includes a single order. Plasmodiophorales and one family Plamodiophoraceae.

PLASMODIOPHORA BRASSICAE

(Club Root of Cabbage)

Plasmodiophora brassicae is an obligate endoparasite in the roots of members of family Brassicacae. It causes clubroot or finger-and-toe disease of brassicas.

LIFE CYCLE

Life cycle of *Plasmodiophora brassicae* is studied in the tissue culture of *Brassica napes* (turnip) and is confirmed during studies of clubbed roots in the soil However all the detail regarding the life cycle are not clear.

Somatic Phase

The somatic phase of slime mold is a plasmodium,a free-living creeping multinucleate mass of protoplasm usually enveloped by a slime sheath that totally lacks cell wall. The whole mass is converted into one or more fruiting bodies, which bear spores..The plasmodia are found in host cell and a mature plasmodium contains about 30 diploid nuclei.

Resting Spores

By the time host dies the plasmodium mature, fills the host cells, undergoes meiosis and its entire protoplasm is converted into rounded resting spores. The resting spores have spiny walls and these are released by decay of roots. They may lie dormant in the soil for 7 or 8 year before germination.

Primary Zoospores & Root-Hair Infection

Under favorable conditions the resting spores germinate to produce biflagellate primary zoospores.These swim for some time and when come in contact with root hair wall, the body of zoospore becomes flattened, the flagella coil around the body of zoospore becomes flattened, the flagella coil around the body and a pseudopodium like extension develops from zoospore. The zoospore withdraw its flagella and encrypts. A vacuoles, lipid bodies and a long tube containing a bullet-shaped stylet develops. The tube becomes attached to the root hair through an evafination of the tube called adhesorium. The vacuole enlarges and thrusts stylet through the host wall. The parasites is injected into the host cell as a small spherical amoeba (myxoamoeaba)

Primary Plasmodium &Zoosporangia

Within the infected root hair, the amoeba divides rise to many unincleate amoeba. Later the nuclei of amoebae divide and small multinucleate plasmodia divide to form many spherical thin-walled zoosporangia lying packed together in the host cell. Each zoosporangium develops four to eight uninucleate zoospores. The mature zoosporangium becomes attached to the host cell wall and pore develops at this point through which the zoospores escape.

Secondary Plasmodium

The zoospores behave as gametes and fuse, however the plasmogamy is not followed by karyogamy immediately. The binucleate zoospores are able to re-infect the root and intimate the formation of binucleate secondary plasmodium that penetrate root cortex. The plasmodium enlarges and repeated nuclear division takes place and the cell containing them become hypertrophied. Later the plasmodia move into medullar ray cells and in the vascular cambium. At this stage the root tissue shows a mottled appearance. When the growth of plasmodia is complete nuclear fusion(karyogamy) occurs to produce diploid zygote nuclei. It is followed by meiosis to form haploid nuclei. The cytoplasm undergoes cleavage to produce resting spores that surrounded by a thin wall. They are closely packed together inside the host cell and release into the soil as the root tissue decay.

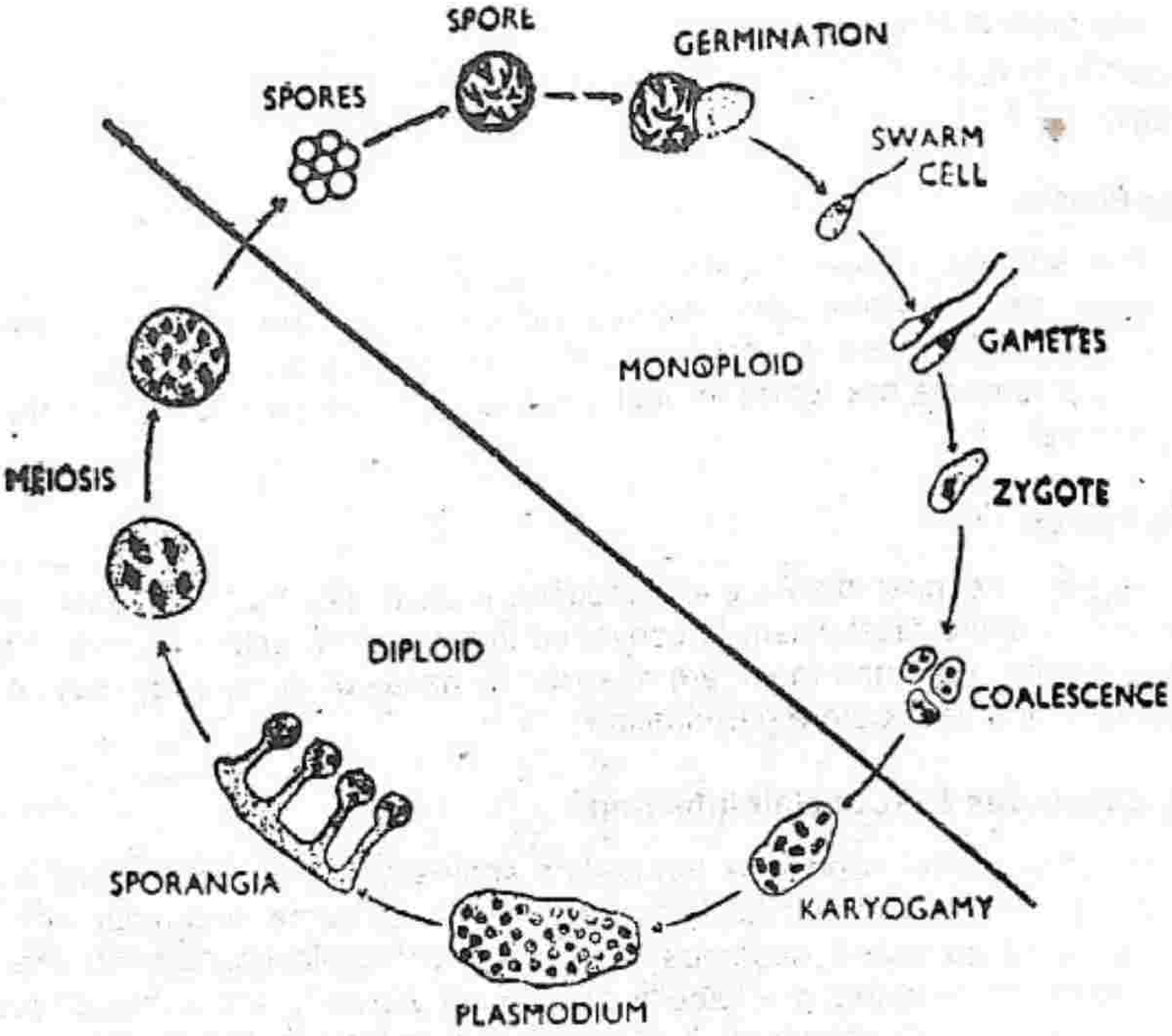


Fig. 5.4: Life Cycle.

MASTIGOMYCOTINA

Zoosporic Fungi

General Characters

1. The Mastigomycotina, a sub-division of Eumycota (true fungi).
2. They include all the flagellate fungi other than the slime molds.
3. The members of the sub-division are characterized by the presence of one or two flagella in their zoospores.
4. A great majority of them are filamentous, producing a coenocytic mycelium.
5. Many forms are unicellular and some unicellular with rhizoids.
6. The sexual reproduction may be isogamous, anisogamous, oogamous or by gametangial contact.
7. The meiosis takes place either in zygote, in special type of sporangia producing meiospores, or in gametangia.
8. The members of the sub-division are characterized by haplobiontic-haploid or diplobiontic life cycles.

Class:Oomycetes —The Water Molds

The Oomycetes comprises of 74 genera with 580 species. The plants with simplest structures are aquatic either free-living or parasitic on algae, water molds, small animals, and other forms of aquatic life. The complex Oomycetes are parasites of terrestrial plants and pass their whole life in the host. The spores are carried to the other hosts by wind. The spores of terrestrial species are flagellated indicating their aquatic ancestory.

The members of the class exhibit following characteristics:

i. The thallus ranges from simple unicellular to a much branched, filamentous mycelium that grows profusely in the substratum.

ii. Most of the Oomycetes are eucarpic. The asexual and sexual reproductive organs occur in most species. In Oomycetes that parasitize higher plants several asexual generations are produced during the growing season, but only a single sexual generation is produced during the growing season.

iii. Asexual reproduction is by reniform (kidney-shaped) or pyriform (pear-shaped) zoospores with a pair of flagella, one tinsel and the other whiplash type. In some species the sporangium directly acts as a spore and germinates by a germ tube to produce a mycelium.

iv. The sexual reproduction is oogamous and is brought by gametangial contact and the meiosis is gametangial rather than zygotic. In simplest forms the whole of the thallus act as a gametangium. In complex forms usually one or more uninucleate oospheres (eggs) develop in an oogonium which upon fertilization develops into oospore within the oogonium. The name Oomycetes originates from oospore (Gr. oon=egg + spora=seed, spore).

The Oomycetes differ from other fungi in many respects, such as:

i. The zoospores are biflagellate with one tinsel type flagellum directed forward and the other whiplash type directed backward.

ii. The presence of glucans mostly, cellulose in some cases, and absence of chitin in most of the species, in the cell walls.

iii. The sexual reproduction is oogamous by gametangial contact.

iv. The meiosis is gametangial.

PYTHIUM

Kingdom: Fungi
Phylum: Heterokontophyta
Class: Oomycetes
Order: Pythiales
Family: Pythiaceae
Genus: *Pythium*
Species: *P. debaryanum*

Habitat

Phythium is largest genus of the family and is represented by 92 species. The genus *Phythium* is common in the soil as well as in fresh water. Its various species live as saprophytes on decaying plant material. Some of them live as parasite and causing a disease known as Damping Off on various crops like tobacco, mustard etc. The species responsible for this disease is *Phythium debaryanum*. Some species are parasitic on certain fresh water algae.

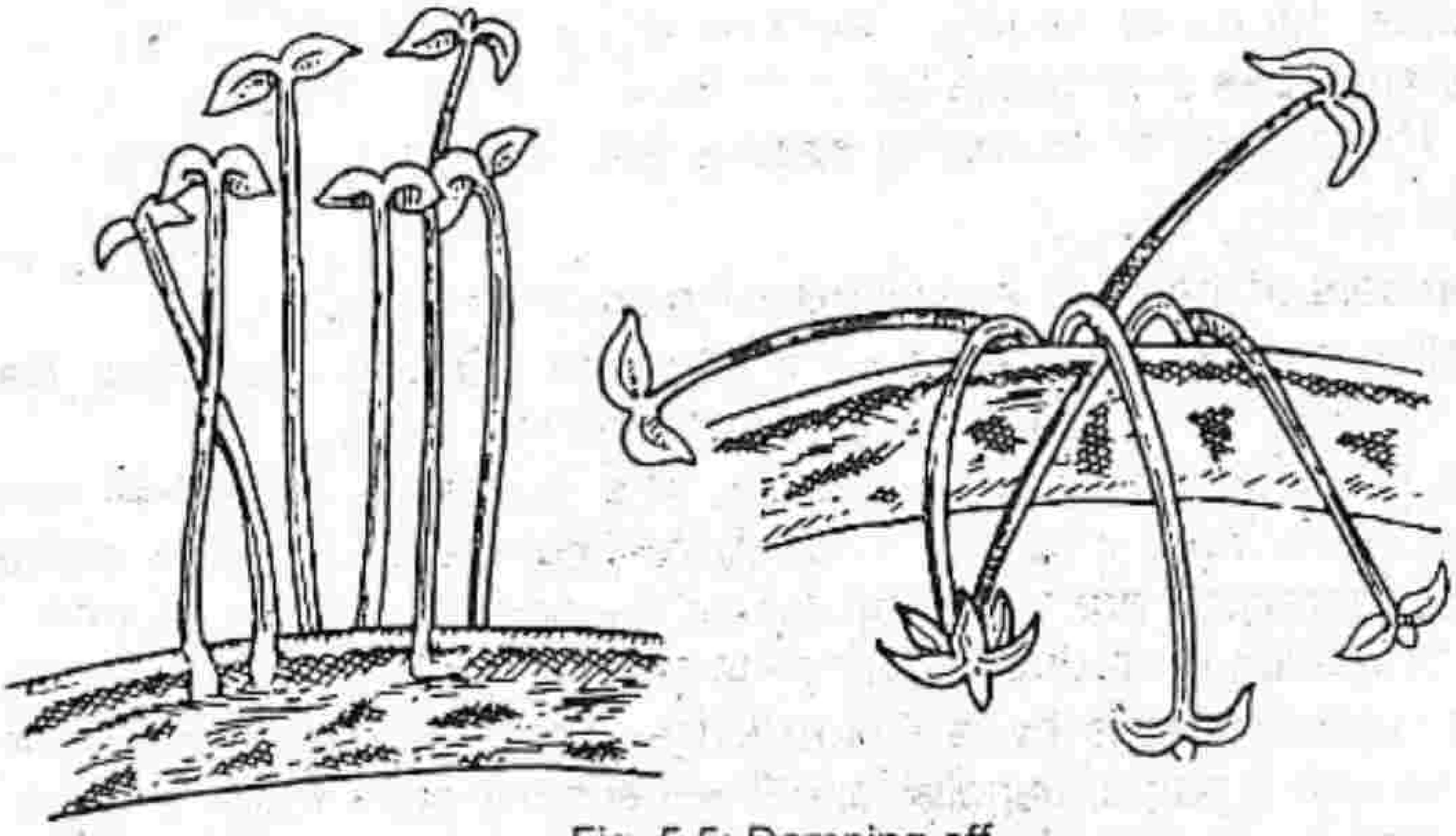


Fig. 5.5: Damping off.

Vegetative structure

The mycelium consists of narrow, coenocytic unseptate and branched hyphae. Hyphae may grow intercellularly or intracellularly but no haustoria are produced. The hyphal wall is formed of cellulose impregnated with chitin. The mature hyphae may become septate.

Reproduction

Asexual

Asexual reproduction takes place by the formation of kidney shaped zoospores bearing two flagella. The flagella are produced laterally on the concave side. The spores are produced in the sporangia that are produced terminally.

During the formation of zoospores, contents of the sporangium come into the delicate vesicle which is borne on the tip of papilla. The cytoplasm then divided into uninucleate parts, each of which is metamorphosed into biflagellate zoospores. The zoospores escape by the rupture of the vesicle wall. Each zoospore after swimming for some period settles down and germinates to produce a new mycelium. Abundant moisture favor the germination of zoosporangium.

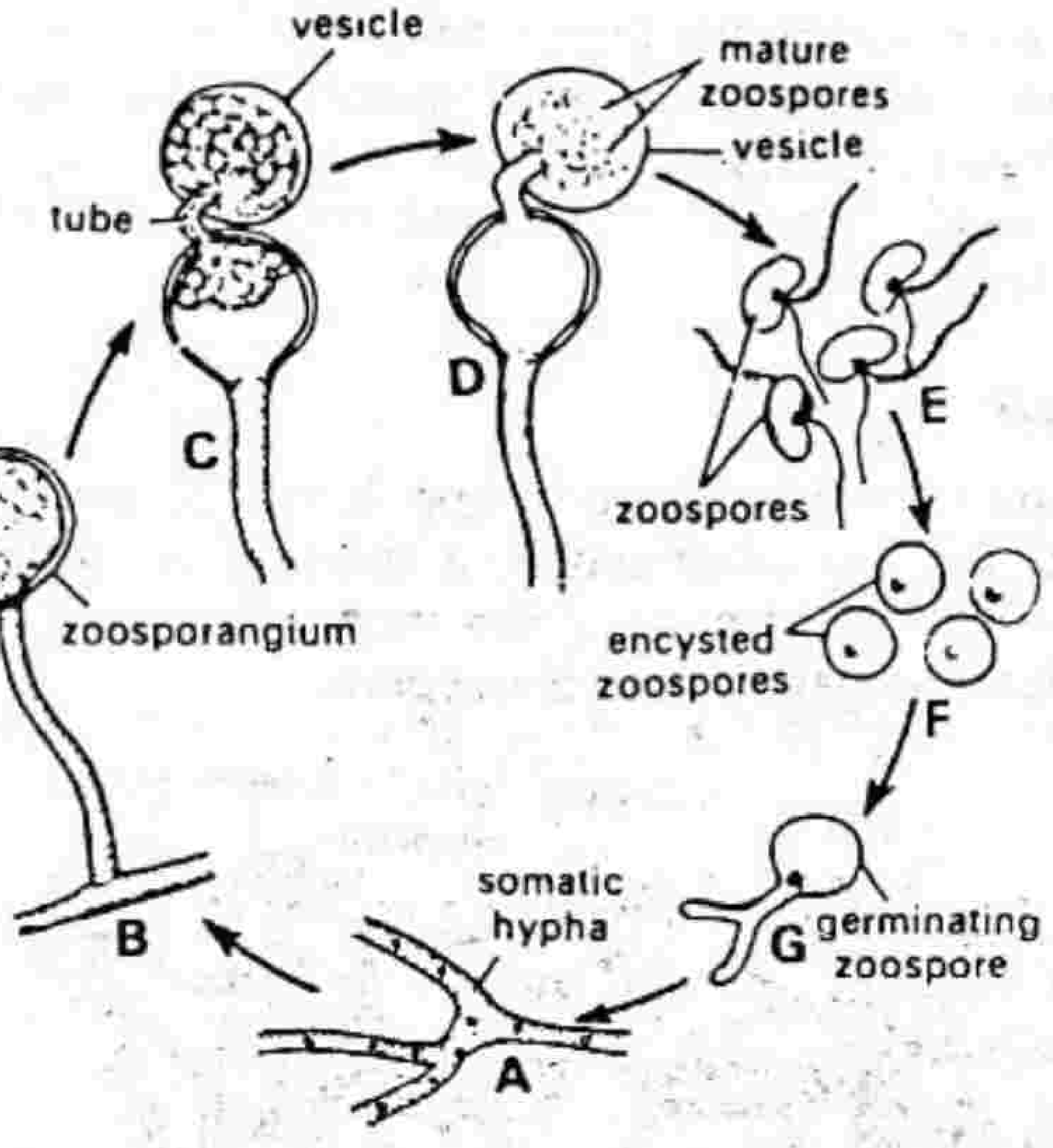


Fig. 5.6: Asexual life cycle.

Some times the sporangia become detached from the hypae and are referred as conidiosporangia. Depending on the environmental conditions the detached sporangium may either produced zoospore or may germinate directly to produced hypae. So it behave like a true conidium. Aboundant moisture favour zoospore production while, dry conditions favour the direct production of hypae.

Sexual Reproduction

Sexual reproduction is oogamous type. Oogonia and antheridia are produced close to each other. In homothelic species the anthredium grow just below the oogonium.

Antheridium

The antheridium is club shaped structure and is closely applied to the oogonium. During the formation of antheridium, the tip of the hyphae act as antheridial initial this tip is swollen and nuclei and cytoplasm is transferred in this swollen portion. This portion is separated from rest of the hyphae by the formation of septum. The young antheridia are multinucleated but at maturity all the nuclei are disintegrated and only one nucleus function as male nucleus. It undergoes meiosis prior the fertilization.

Oogonium

The Oogonia are spherical or globose and usually developed at the tip of the hyphae. The tip of the hyphae act as oogonia initial, which is then swollen to form oogonium. The wall of the oogonium is separated from rest of the hyphae by the formation of septum. Each mature oogonium is globose and contains a single oosphere which is surrounded by a layer of cytoplasm known as periplasm. Young oospore is multinucleated but laterally only one nucleus persists.

Fertilization

Fertilization takes place by the formation of fertilization tube. This tube from the antheridium pierces the oogonial wall, the periplasm enters the oosphere. The male nucleus from the antheridium passes through this fertilization tube and enter the oosphere. The nuclei fuses together to form zygotic nucleus. The fertilized egg secretes a thick wall and changes to oospore.

Germination of Oospore

Oospore germinates after a period of rest. It may produce the mycelium directly or may produced a short hyphae which ends in a sporangium. A high temperature favors mycelial formation while low temperature favors the production of zoospores. Reduction division takes place before the germination of oospore.

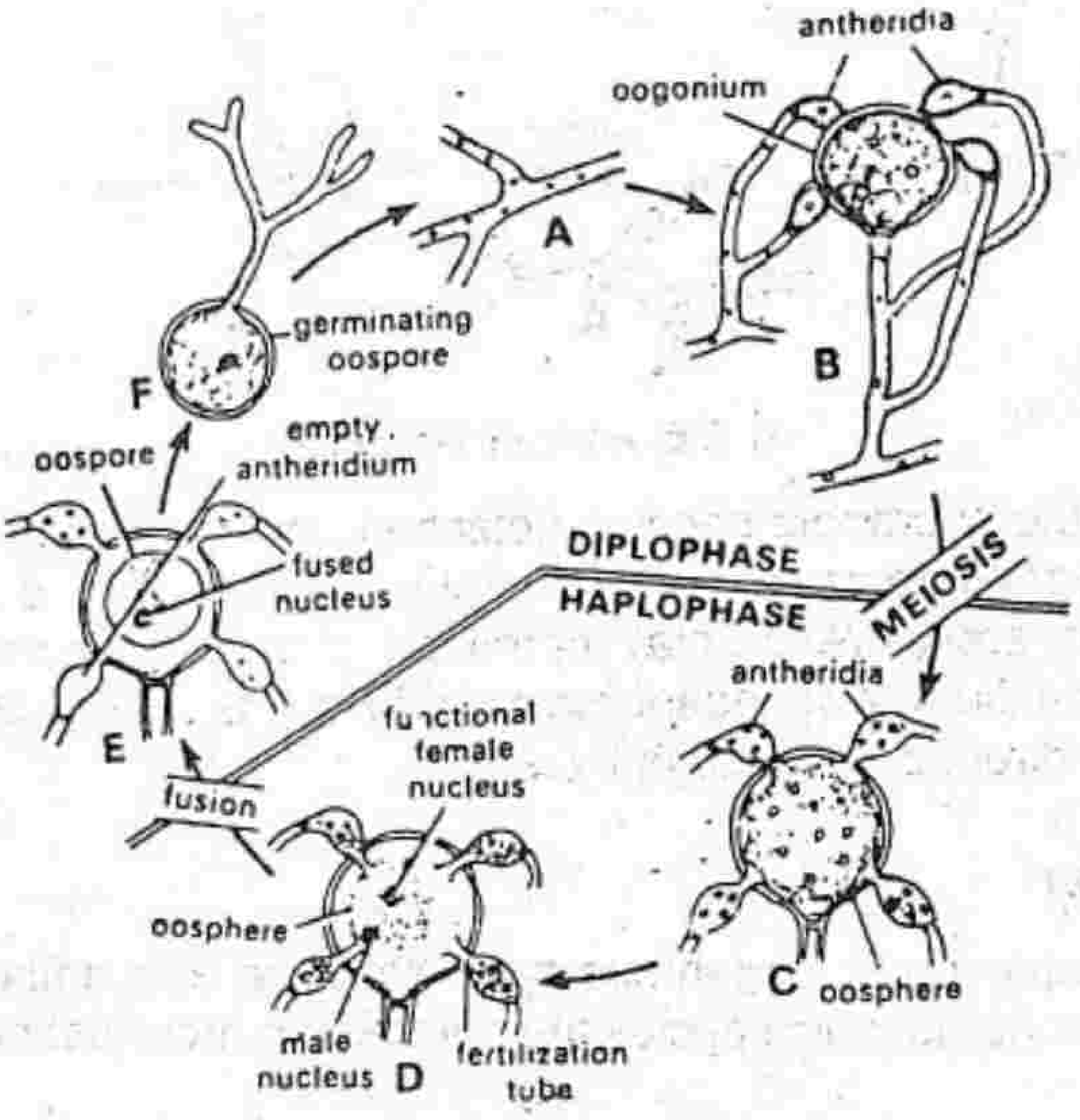


Fig. 5.7: Life Cycle of Pythium

MUCOR

TAXANOMIC POSITION

Kingdom: Fungi
Division: Mycota
Class: Zygomycetes
Order: Mucorales
Family: Mucoraceae
Genus: *Mucor*

Habitat

Mucor appear more readily on damp horse dung when kept under a bell jar. It is also found in soil, bread and other food materials.

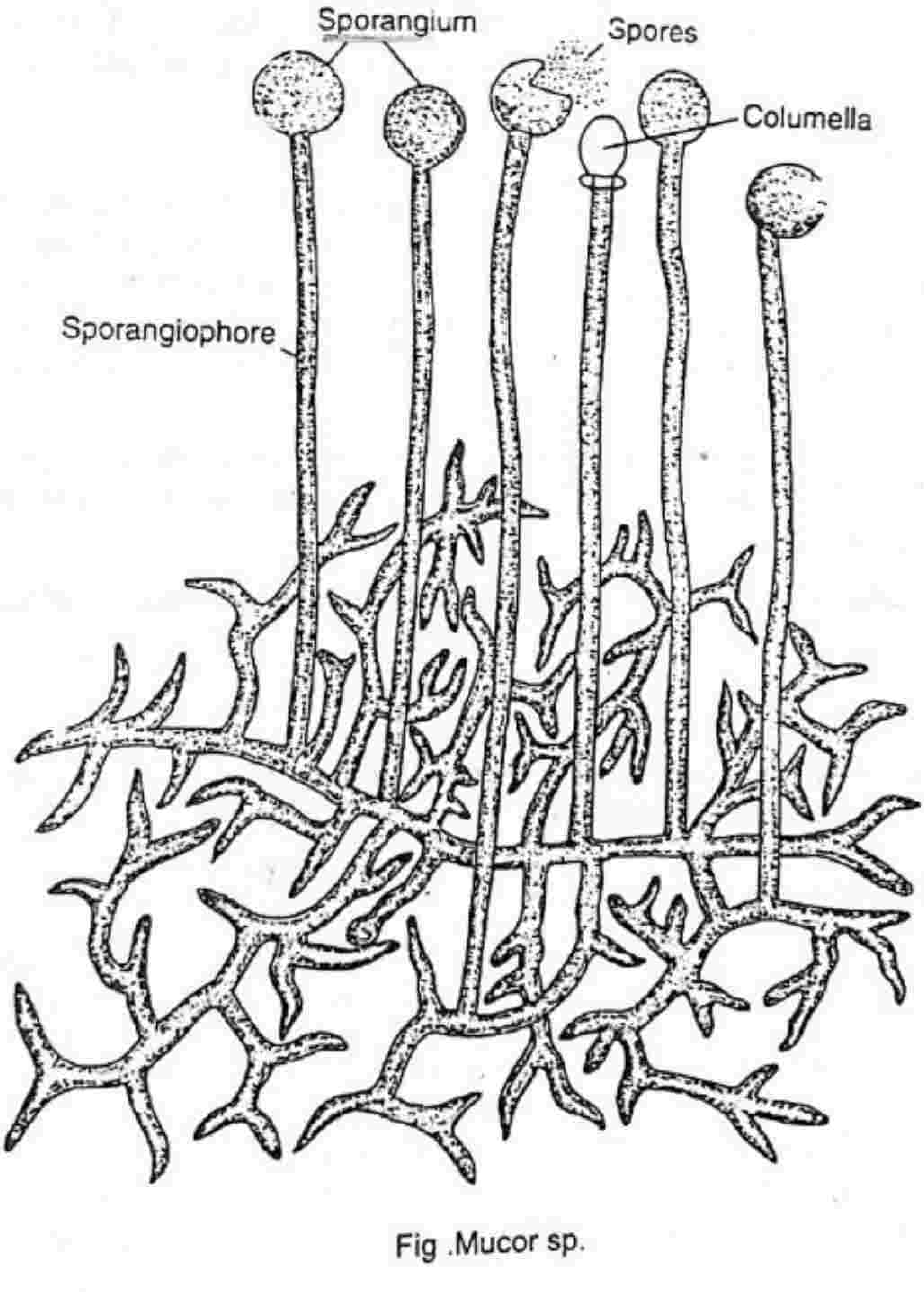


Fig .Mucor sp.

Vegetative structure

The mycelium consists of numerous, selender, freely branched filaments, the hyphae. The hyphae form a fluffy, white mass called mycelium. It soon enter in the reproductive phase. Numerous black, pin head like structure developed on the mycelim called as sporangia. The hyphae are coenocytic and aseptate. During the vegetative phase the mycelium consists of stolon hyphae and rhizoidal hyphae. The rhizoidal hyphae help in the absorption of nutrients from the substrate. The cell wall is made up of chitin and cellulose is absent. The cytoplasmic organelles like mitochondria, endoplasmic reticulum etc is present in the cell.

(1)

Vegetative Reproduction

(i) Fragmentation

Fragmentation consists in the separation of hyphae from aerial mycelium. These are known as Fragment. Each fragment has ability to grow into new mycelium.

(ii) Chlamydospore Formation

Under unfavorable condition the fungus produced special modified thick walled resting cell called as chlamydospores. They contain food and very resistant to desiccation. On return of favorable conditions, it germinate to produced new mycelium.

(2)

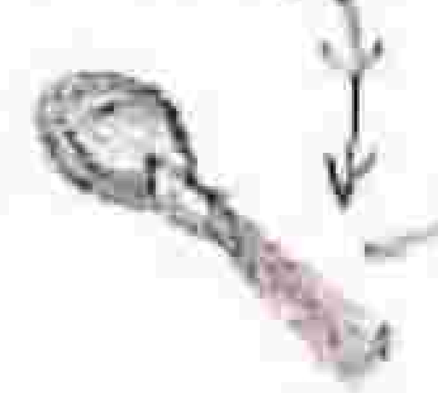
Asexual Reproduction

by (sporangiospores)

Asexual reproduction takes place by formation of non-motile, multinucleate sporangiophore. The sporangia arise singly and terminally at the tips of sporangiophores. The young sporangium is white spherical structure. At maturity it turns black due to the production of spores. In the centre of sporangium is a large dome-shaped structure called columella. The sporangia are haploid. They are produced on haploid mycelium and contain haploid spores.

The spores are dispersed after the rupturing of the sporangiophore. They are dispersed by wind. The spore is non-motile, oval and contain protoplast surrounded by single layered cell wall.

Under suitable condition, the spore germinate by the formation of germ tube. The hyphae arises from the germination tube and spread in all direction.



→ hyphae → mycelium

(3)

Sexual Reproduction

Mucor display a sexual process which is of conjugation type. It consist of fusion of entire cell contents of two gametangia.

↓ zygospores

Gametangial Copulation

Sexual reproduction takes place by gametangial copulation. The fussion gametes are multinucleated and distinct genetically. The sexual process starts with the formation of two special hyphae termed zygophores. They arises near the apices of active growing somatic hypae of + and − strains. They are chemically induced. The zygophores meet and adhere in pairs at their tip to form fusion septum. The tip of zygophores begain to swell due to flow of cytoplasm and nuclei into them. They are called as progametangia. The combined protoplast in prozygosporangium containing a number of diploid nuclei is called as zygospore. It secretes a thick wall and become into zygosporangium.

Germination of Zygospore

Under suitable condition the zygospore germinate to produce germ tube. The first division is reductional division. So, numerous haploid nuclei are produced of opposite strain. The germ tube soon bears a terminal sporangium. The protoplast produce non-motile spores called as germ spores. The germ spore on falling on suitable substratum germinate to form the mycelium.

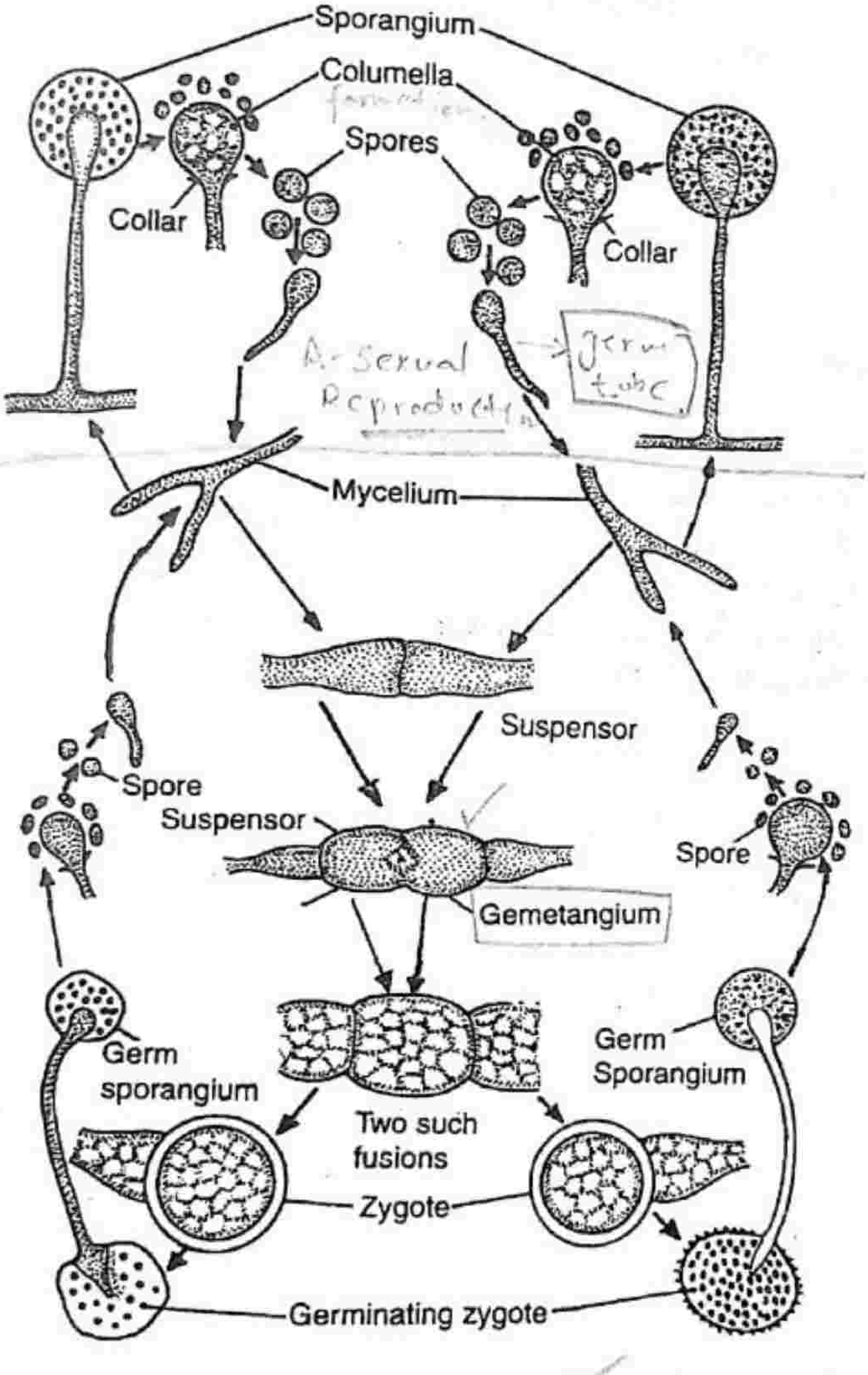


Fig . Life cycle of Mucor

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Give characteristics of myxomycota.
2. What is plasmodium in fungi.
3. Describe resting phase in Plasmodiophora.
4. How the club root of cabbage can be controlled.
5. What are oomycetes.
6. What are zoosporic fungi.
7. Give asexual reproduction in pythium.
8. What is damping off.
9. How fertilization in pythium takes place.
10. What is zygospore.

B. Long Questions

1. Describe life cycle of Plasmodiophora.
2. What is the control of club root cabbage.
3. Describe asexual reproduction in pythium.
4. Describe life cycle of pythium.
5. Draw life cycle of pythium.
6. Describe asexual reproduction of Mucor.
7. Describe life cycle of Mucor.

سرسید کی بات

ASCOMYCOTINA

Sac Fungi

The Ascomycotina are more complex fungi than the lower fungi (Mastigomycotina and Zygomycotina). These form the largest group of the fungi and contain about 2720 genera and 28650 species. The Ascomycotina include a wide range of diverse organisms such as yeast, black molds, blue molds, ringworms, powdery mildews, black mildews, cup fungi, morels and truffles.

General Characters

1. The members inhabit a variety of habitat. Some are parasites on plants, others are saprobes living on soil or on decaying logs. A number of Ascomycotina grow on the dung of various animals (coprophilous). A few species are marine and live saprobic life on floating or submerged organic matter, or as parasites on marine algae and angiosperms.
2. Some members of the division, for example yeasts are unicellular; others produce a chain of cells to produce a pseudomycelium.
3. The mycelium is composed of slender septate, profusely branched hyphae.
4. The hyphal cells contain all the typical cellular contents including ribosomes, mitochondria, endoplasmic reticulum, vacuoles, microtubules, lipid bodies, etc. The cells are often uninucleate, but mycelia with multinucleate cells are also quite common.
5. The mycelium is often organized into fungal tissues: plectenchyma, that may be a prosenchyma (fungal hyphae loosely woven and do not lose their individuality) or pseudoparenchyma (individual hyphae lose their identity, becomes rounded to form nearly isodiametric cells resembling parenchyma cells). These tissues are usually associated with spore bearing structures, the ascocarps, but these also compose certain somatic structures such as sclerotia and stromata.
6. The ascomycetes reproduce both asexually and sexually usually. But some genera reproduce by vegetative multiplication.
7. The asexual stage is represented by conidia or spores and is often termed as imperfect stage.
8. The sexual stage is characterized by the formation of an ascus in which sexual spores, the ascospores, develop. This stage is called ascigerous or perfect stage.

Sexual Reproduction

The sexual reproduction in ascomycetes is oogamous and characterized by formation of sexual spores, the ascospores. These spores are produced in specialized structures, the asci contained in special fruiting bodies, the ascocarps. In some cases asci may be naked.

The plasmogamy phase of sexual reproduction is accomplished by a variety of methods including gametangial copulation, gametangial contact, spermatization, and somatogamy. The sex organs are flask shaped ascogonia (female sex organ), each having a long, hair-like hypha, the trichogyne; and club-shaped antheridia or tiny spore-like spermatia (male sex organs). When a trichogyne contacts a compatible antheridium or spermatium, the wall of contact dissolves and the contents of the male gametangium enter the ascogonium. The nuclear fusion (karyogamy) is delayed and the male and female nuclei lie side by side.

Structure and Development of Ascus

The ascus (pl. asci) is an elongated, either club-shaped or cylindrical, structure that represents a single cell in which ascospores are produced. The asci may be stalked or sessile, and arise singly or present in the form of a definite layer known as hymenium. Sometimes sterile, elongated hairs called paraphyses arise between the asci. These are supposed to be helpful in dispersal of asci and ascospores.

The male and female nuclei divide and form pairs (one male and the other female). These paired nuclei are called dikaryons. The paired nuclei arrange themselves under the ascogonial wall. Buds arise from the ascogonial wall in front of each pair of nuclei. The nuclei migrate into these buds and each bud grows into ascogenous hyphae. The nuclei divide repeatedly by mitosis and become distributed in the ascogenous hypha. The hypha becomes septate by formation of a septum between the two daughter nuclei of each mitosis. This is the dikaryotic phase. Each ascogenous hypha produces a branch from one or more of its dikaryotic cells, the tip of which bends to form a hook or crozier, containing two compatible nuclei. The nuclei divide in such a way so that the spindles are oriented perpendicularly. A septum is formed between the two daughter nuclei of each division, so that the crozier is divided into three cells. The penultimate (hook cell) is dikaryotic, containing one nucleus of each sex, whereas the tip and basal cells of the crozier contain one nucleus each, of different origin. The nuclei in hook cell of the crozier fuse to form ascus mother cell. It elongates and develops into an ascus.

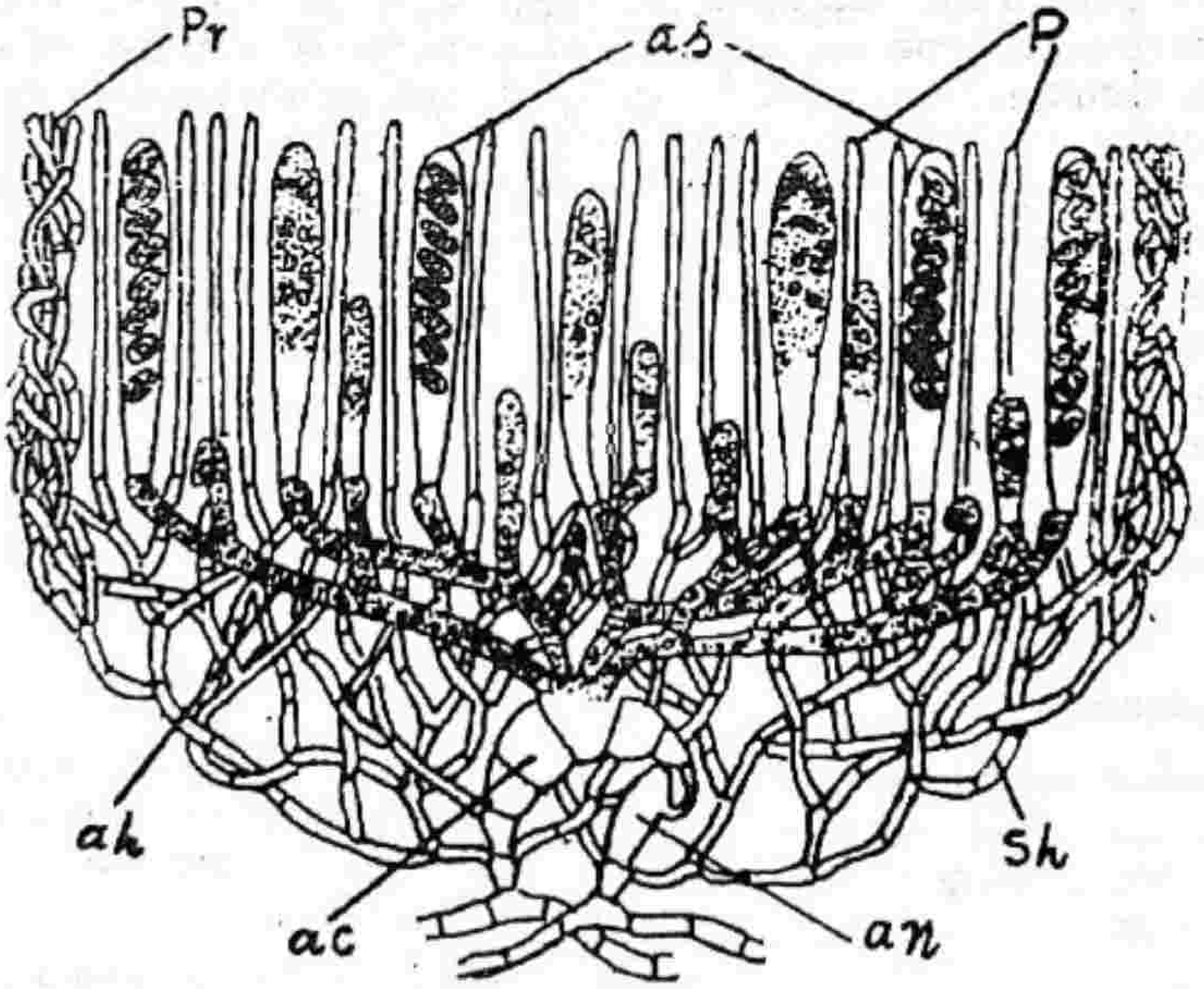


Fig. 5.8: V.S. of Ascocarp.

Structure and Development of Ascospores

The ascospores vary greatly in size, shape, colour, wall ornamentation, and other characteristics. They range from globose to thread-like in shape; and from colourless to black in colour.

The diploid nucleus in the ascus mother cell undergoes meiosis, producing four haploid nuclei, which divide again by mitosis producing eight nuclei. A system of membranes surrounds and invaginates around the nuclei. A thicker wall is formed around each uninucleate unit which develops into an ascospore. The surrounding cytoplasm in which the spores are embedded is the epiplasm, and the whole process is called free cell formation.

Structure, Development of Ascocarps

While the development of asci and ascospores is taking place, the stalk of the ascogonium and the hyphal cells below it are stimulated to grow and form a wall, which surrounds the sexual apparatus and forms a fruiting body, the ascocarp. An ascocarp consists of protective covering, asci, and other sterile structures among the asci such as paraphyses. Ascocarps may be formed singly or in groups. These may be superficial, erumpent (pushing through the tissues of the substratum), or deeply embedded in the substratum, that may be host tissue or hyphal stroma.

FRUITING BODIES IN ASCOMYCETES

The plasmogamy in the Ascomycetes not only results in the production of ascogenous hyphae but vegetative hyphae in the vicinity of ascogonium are also stimulate to growth. Growth of such hyphae results in the formation of a fruit body or ascocarp into which asci are produced. Following are the general fruiting bodies in ascomycetes.

1. Cleistothecium

The fruiting body is rounded without any opening. The asci are globose and are arranged irregularly with in it. The ascospores are released by the dissolution of ascus wall and further by disintegration of the ascocarp wall.

2. Perithecium

The fruiting body is flasked shaped structure having an opening called ostiole. The asci are arranged in a layer forming the hymenium on the inner surface of ascocarp. Interspred among the asci may be sterile hair like structure called paraphyses.

3. Apothecium

The fruiting body is cup shaped structure. The asci are arranged in a layer forming the hymenium on the inner surface of ascocarp. Interspred among the asci may be sterile hair like structure called paraphyses. Apothecium may be stalked or sessile.

4. Ascostroma

This is not true fruiting body but ascogenous hyphae grow inside the previous formed stroma. The asci are produced in the cavities formed by the dissolution of the tissues of stroma. There may be many asci in the in each cavity which opens to the out side by the formation of an aperture. No distinct walls are present around the group of asci.

Release and Germination of Ascospores

When the ascospores are mature, these are released. In species where ascocarps are not formed these are released by bursting or deliquescence of asci, and in species where the asci are enclosed in ascocarps these come out through ostiole (perithecium) or by bursting of wall of the ascocarp (cleistothecium). The released spores are carried and distributed by wind, water, insects or other agencies. In a large number of ascomycetes, ascospores are forcibly ejected from the ascus by puffing action, e. g., in morels.

Under favourable conditions ascospores germinate by one or more germ tubes that develop into a septate mycelium. In many yeasts and some other fungi the ascospores multiply by budding instead of producing germ tubes.

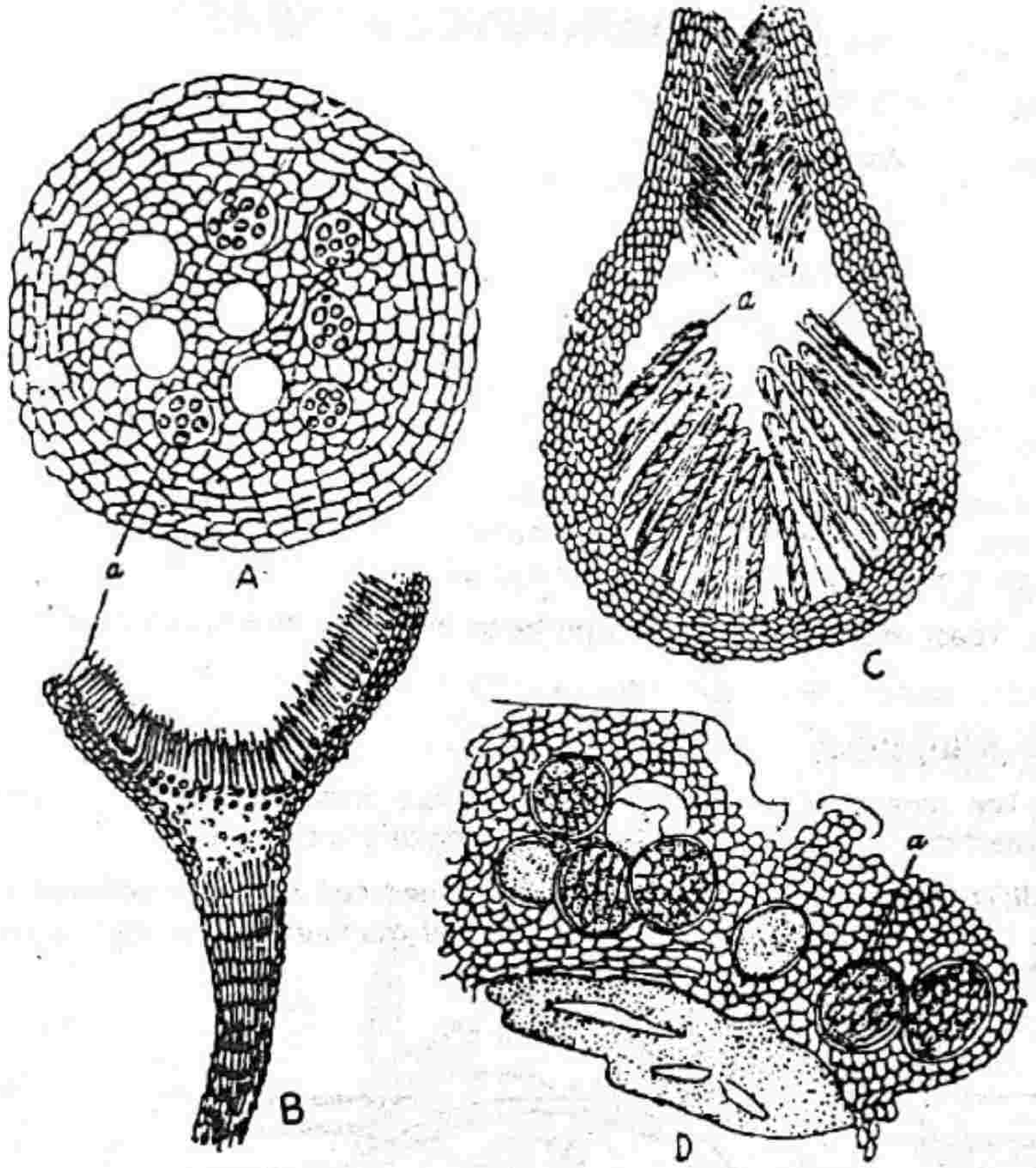


Fig. 5.9: Different types of Ascocarp. A: Cleistothecium. B: Apothecium. C: Perithecium. D: Ascostroma.

SACCHAROMYCES *(YEAST)*

Kingdom: Fungi
Division: Ascomycota
Class: Saccharomycetes
Order: Saccharomycetales
Family: Saccharomycetaceae
Genus: *Saccharomyces*
Species: *S. cerevisiae*

Saccharomyces is characterized by rounded spores and causes vigorous fermentation of sugars. It contained about 41 species, among them *Saccharomyces cerevisiae* is most common. These are the unicellular member of Ascomycetes.

Habitat: Yeast are common in soil, on decaying fruits and on substrate rich in sugar supply.

Vegetative Structure:

Shape: The vegetative cells of common yeast are unicellular, oval or oblong in shape. Some time it may be pseudo-mycelium consisting of chain of cells.

Cell wall: The protoplast is bounded by well defined cell wall. The cell wall is composed of three layers. The outer layer is composed of mannan-protein and some chitin, the middle of glucon and the inner of protein glucon.

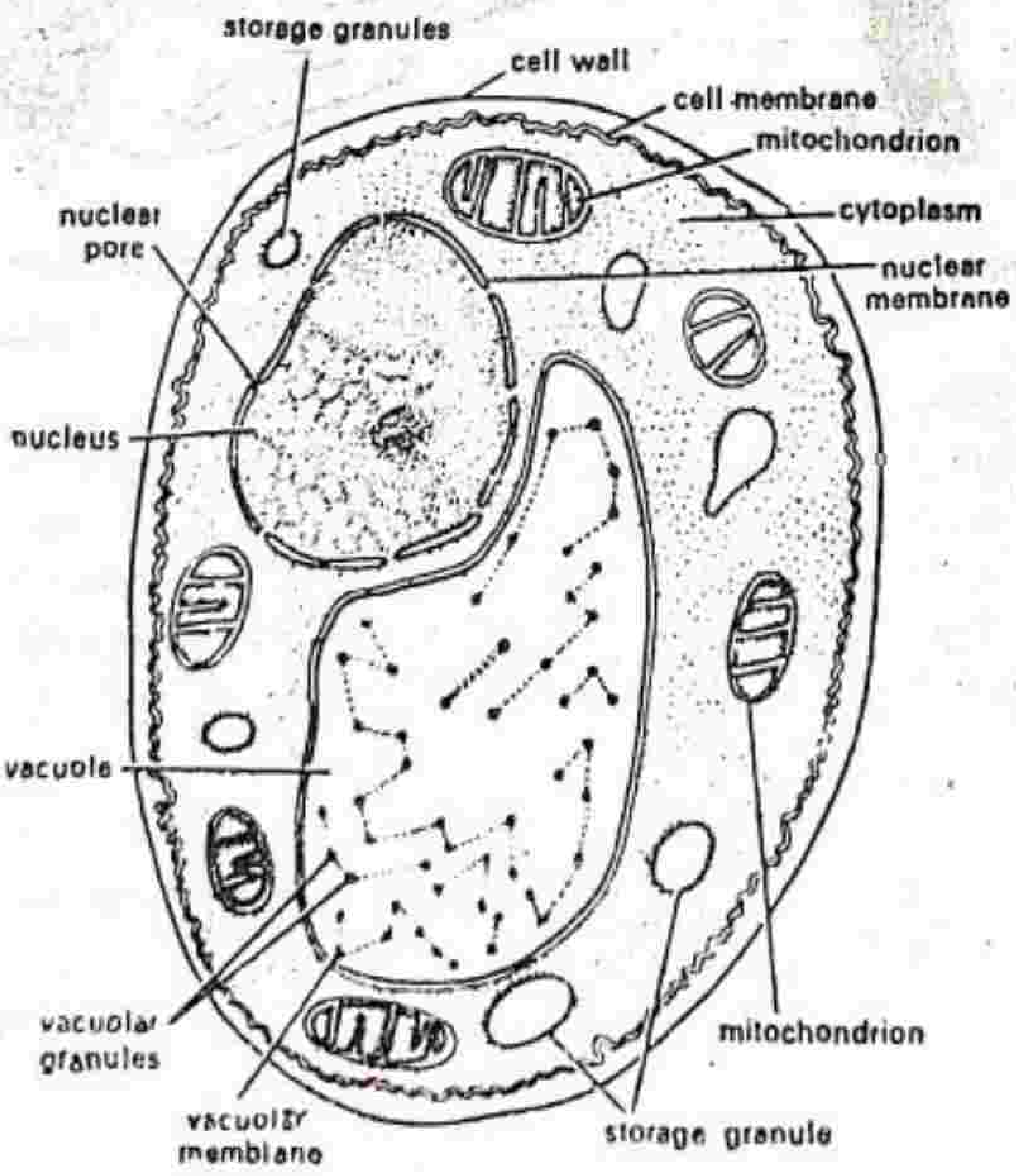


Fig. 5.10: A Vegetative Cell.

Cell membrane: The cell membrane is unit membrane and is variously ornamented.

Cytoplasmic organelles: consists of mitochondria, endoplasmic reticulum, ribosomes and lipid granules (sphaerosomes).

Nucleus: A small nucleus lies embedded in the cytoplasm on one side of the vacuole.

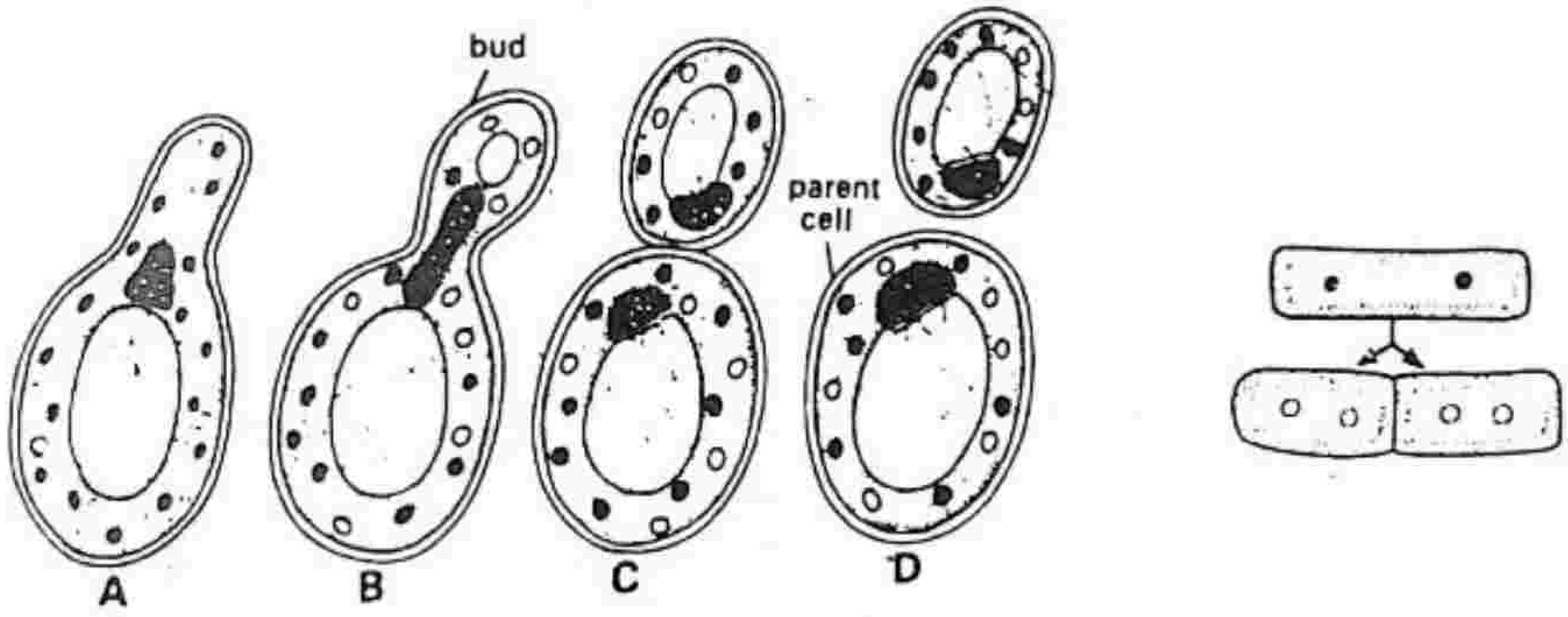
Reproduction:

Asexual reproduction

Saccharomyces reproduce asexually by budding. During the formation of bud, a small protuberance is produce on the surface of the cell. The protuberance increase in size and the cytoplasm from the parent cell flows into it. The nucleus of the parent cell divides into two and the daughter nuclei migrate into the bud. This bud is separated from the parent cell and increase in size by living as an independent plant.

Some time bud may produce its own bud before it become detached from the parent cell. In this way several cells may held together in a long chain.

In *Schizosaccharomyces octosporus*, commonly called fission yeast exhibits multiplication by simple cell division called fission. It is unicellular and occurs on fruits such as grapes and figs. The cells of the fungus are spherical to ellipsoidal, vacuolated, and uninucleate. The nucleus of the cell divides followed by the wall formation to produce two daughter cells. Recently divided cells may remain adherent, or they may separate promptly.



Budding.

Fig. 5.11: Saccharomyces —Budding and fission.

Sexual reproduction

Sexual reproduction in *Saccharomyces* takes place by the union of two haploid vegetative cells, giving rise to a diploid cells. *Saccharomyces cervices* is heterothallic, consisting of two mating types. The sexual reproduction results in formation of asci, each of which produces four ascospores, two of each mating type. The cells of one mating type secrete substance that stimulate the cells of opposite mating type to elongate and move towards the cells of other mating type. Plasmogamy and karyogamy take place and the diploid cells eventually change into an ascus. First division is reductional division and four haploid nuclei are formed. On ascospore is formed around each haploid nucleus and in this way four ascospores are produced. These ascospores are released by rupturing the ascospore wall. Each ascospore on liberation behave as vegetative cell and reproduce asexually be budding.

In *Schizosaccharomyces octosporus* two adjacent cells produce short protuberances that meet. The tips of the cells dissolve to accomplish plasmogamy and karyogamy. The zygote nucleus soon undergoes three successive nuclear divisions, resulting in the formation of eight nuclei. The first two divisions are meiotic and the third one mitotic. An ascospore is delimited around each of eight nuclei leaving epiplasm around them. Therefore, the zygote is transformed directly into a single ascus, which ultimately liberates the ascospores when its wall deliquesces. The ascospores reproduce asexually by fission.

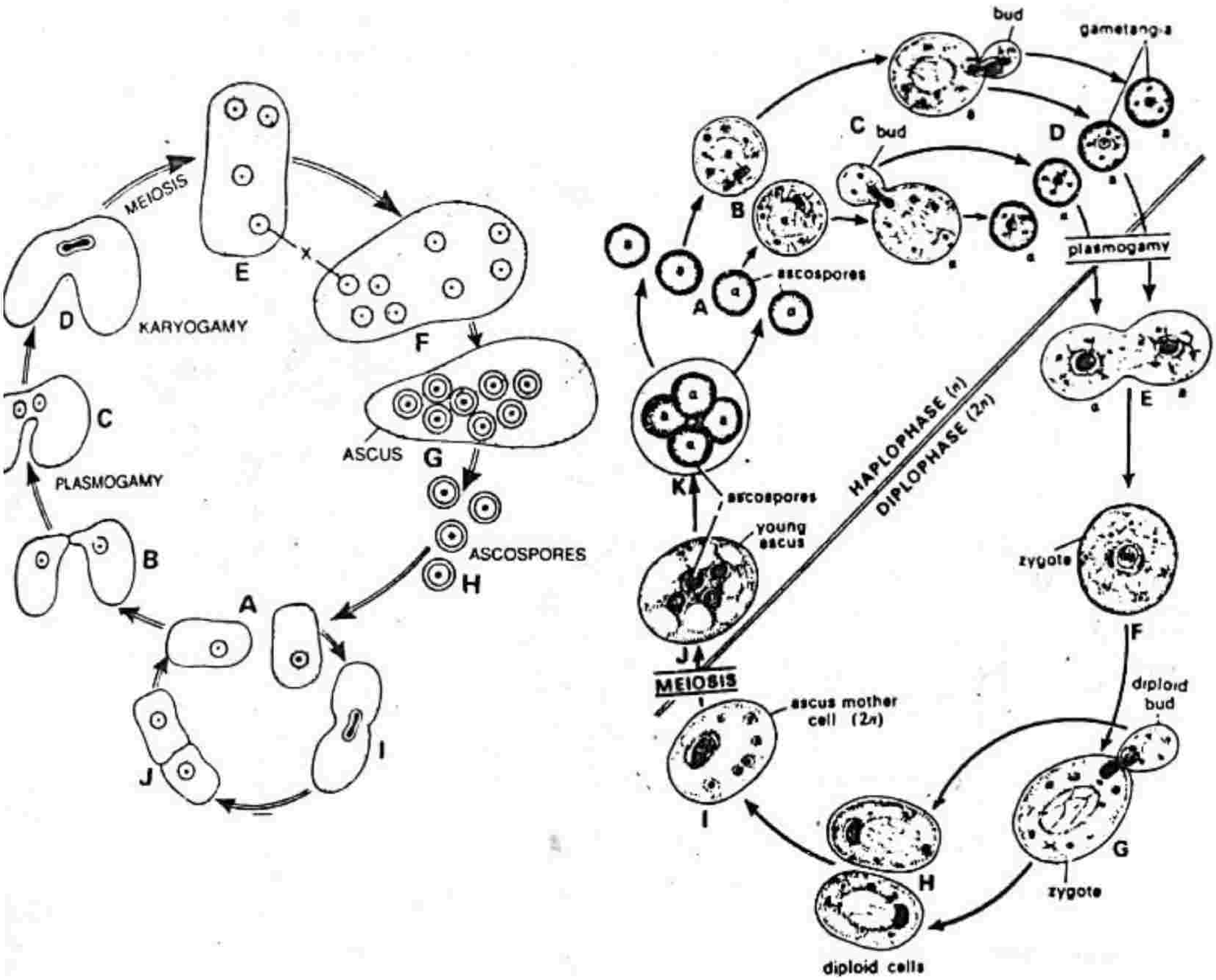


Fig. 5.12: Saccharomyces — Life cycles.

C.W
P. Notatus

PENICILLIUM

4-layer

R.F.M

oil globules

Kingdom:	Fungi
Division:	Ascomycota
Class:	Eurotiomycetes
Order:	Eurotiales
Family:	Trichocomaceae
Genus:	*Penicillium*

+ نیلی

Penicillia are common and cosmopolitan genus, commonly known as blue and green molds.

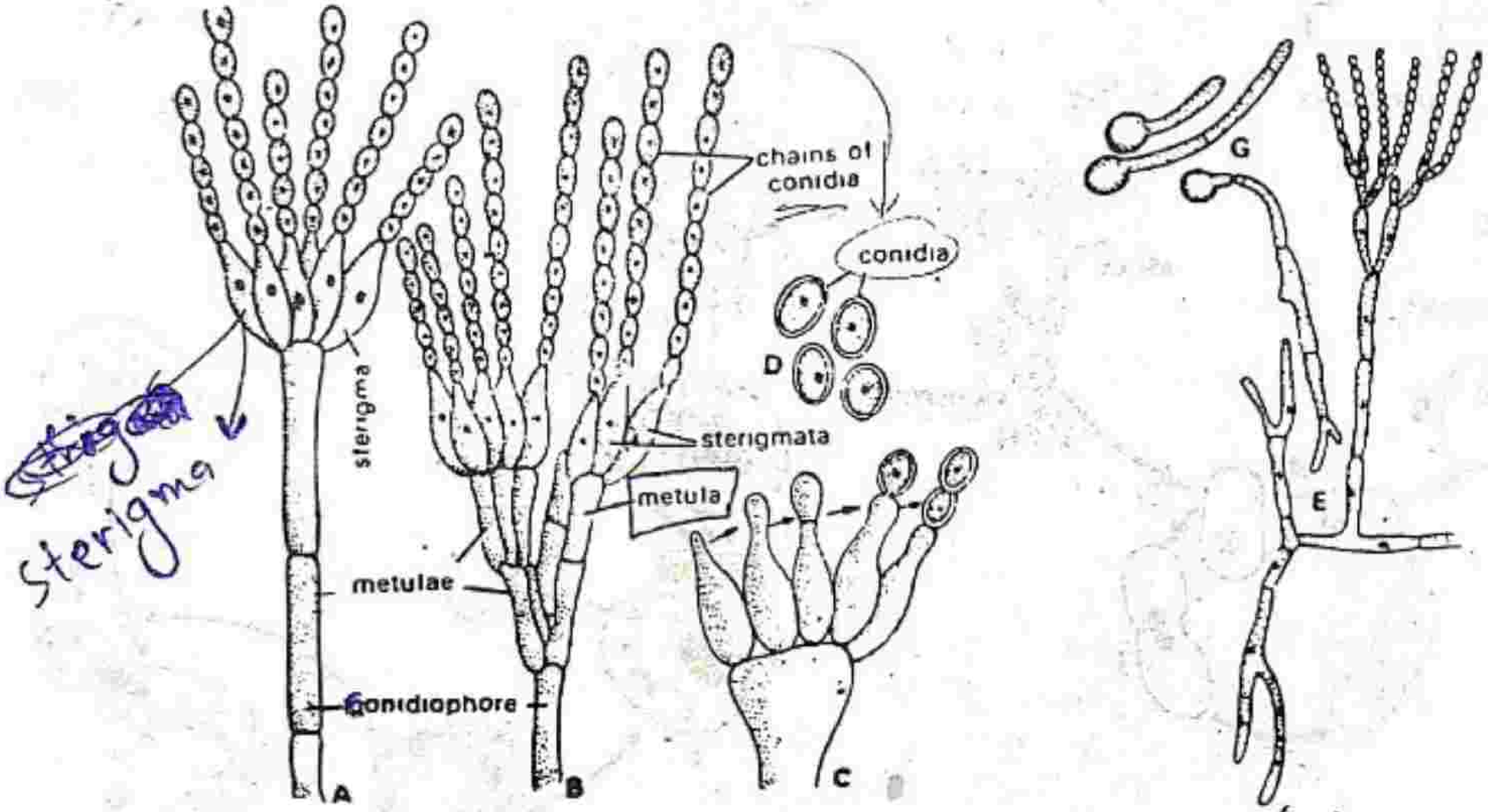


Fig. 5.13: Vegetative Structure.

(asexul spore ~~in hyphae~~)

Occurrence

The fungus is found on wide variety of substrate such as citrus fruits, jellies, foodstuffs, old leather, paper and in the soil. The conidia of Penicillia are found everywhere in the air and in the soil. Contamination of Flemming's bacterial culture by *Penicillium notatum* led to the discovery of penicillin.

PLANT BODY

The Mycelium (veg. part of fungus)(consist of thread like hyphae)

The mycelium is well developed and is profusely branched. It is composed of colourless, slender, tubular, branched, and septate hyphae. Some of the hyphae may invade the substratum to absorb nourishment from the substratum, whereas the others spread on the surface of the substratum. (The mycelium becomes coloured due to the production of colored conidia.)

Cell Structure

(mycelium → branched + septate).

The hyphae are septate and each cell is uninucleate. The cell wall is microfibrillar and in *Penicillium notatum* it is reported to consist of three or four layers. The outermost layer is composed of glucans, the next of proteins, the third of chitin fibrils embedded in a granular matrix, and the innermost of pectic or hemicellulosic material. The plasma membrane surrounds the cytoplasm in which mitochondria, ribosomes and endoplasmic reticulum is embedded. The reserve food is in the form of oil globules. The septa between the cells have a central pore through which the protoplasm of the adjacent cells remains in contact.

Reproduction

The Penicillia reproduce vegetatively, asexually and sexually.

Vegetative Reproduction :

The vegetative reproduction takes place by fragmentation. During fragmentation the hyphae break up into short fragments which grow by repeated divisions into a new mycelium.

Asexual Reproduction

Asexual reproduction takes place by the production of conidia. The conidia are produced on the conidiophores. The conidiophores are erect, branched in a broom like fashion. Each branch bears short branches at its tip called as metulae. There are group of bottled shaped sterigmata at the tip of each matula. Conidia are produced in chains at tips of sterigmata. The whole group of metulae and sterigmata on each branch is called pencillus.

The conidia are tiny, uninucleate, spore-like structures which may be globose to ovoid in form. The spore wall is pigmented and is differentiated into two layers, an outer thick, ornamented layer, the exine; and an inner smooth and thin layer, the intine. Inside the spore wall plasma membrane is present which encloses the cytoplasm. Mitochondria and ribosomes are embedded in the cytoplasm. The reserve food is the oil globules.

Development of conidia

Each sterigmata is a uninucleated structure. During the production of conidia, the nucleus divided into two. One daughter nucleus along with some cytoplasm migrate into the slightly swollen tip of the sterigma. This portion is then cut off from the rest of the sterigma by the formation of cross wall. The protoplast is then contract slightly and secretes a wall of its own. This process repeated several times and a chain of conidia is produced at the tip of each sterigma. Each newly formed conidium is uninucleated but later on this nucleus divided several times, making the conidium multinucleated.

Germination of conidium:

The conidia germinate by producing hyphae directly on falling on suitable substrate.

Oidia Formation

The *Penicillium* hyphae, when grown in a medium of sugar solution, divide into small, uninucleate segments which become rounded and separate into thin walled spore-like structures called oidia or oidiospores. These increase in number by budding. This is called torula stage and the fungus in this stage brings about fermentation of sugar into alcohol. The oidia when transferred to a solid substratum germinate to form a new mycelium.

Sexual Reproduction

It is the perfect state of *Penicillium*. All the species are homothallic. The sexual reproduction is oogamous. The male sex organs are antheridia and female sex organs are ascogonia.

Ascogonium

A mature ascogonium is a long, erect, multinucleate, tubular structure with curved upper end. It arises from a uninucleate, septate hypha as a finger-like, lateral outgrowth which elongates into an ascogonium. The nucleus of the ascogonium divides many times mitotically to produce 32 or 64 nuclei.

Antheridium

While the ascogonium is developing, a slender uninucleate branch originates from a cell of the same hypha adjacent to the developing ascogonium, or from a neighbouring hypha. This is the antheridial branch. It grows up and coils around the ascogonium. The tip of the antheridial branch swells up and is cut off from rest of the branch to form a uninucleate antheridium.

Fertilization

The tip of the antheridium comes in contact with the wall of the ascogonium and the wall of contact between the two dissolves to form a pore. The protoplasts of the gametangia come in contact with each other through this pore. The antheridial and ascogonial nuclei arrange themselves in pairs. Each pair is called a dikaryon.

Development of Ascus and Ascospores

The stimulus of plasmogamy results in septation of ascogonium into binucleate cells. Some of these segments, usually those present in the middle, produce outgrowths called ascogenous initials which develop into ascogenous hyphae composed of binucleate cells. The tip cells of these hyphae act as ascus mother cells which develops either simply by elongation, or by crozier formation into an ascus. Karyogamy takes place in the ascus mother cell and this diploid nucleus undergoes meiosis to produce four haploid nuclei. A mitotic division results in the formation of eight haploid nuclei. These are transformed into ascospores by free cell formation. The asci are globose or pear-shaped and the unicellular, uninucleate and lens-shaped with a groove around the edge.

Development of Cleistothecium

As soon as the septation of ascogonium and development of ascogenous hyphae starts, the sterile hyphae present at the base of the ascogonium grow upward and surround the sexual apparatus. These hyphae become interwoven to form a hollow, ball-like structure, the peridium, the wall of the ascocarp. The ascocarp continues to grow even after the maturation of ascospores. The ascocarp is without an opening, therefore, is a cleistothecium.

Dispersal of Ascospores and Germination

The asci are evanescent, i. e., dissolve soon after the formation of ascospores, leaving the ascospores free in the ascocarp. The ascospores are released by the decay of the wall of the ascocarp. The ascospores germinate by formation of a germ tube to form a new mycelium.

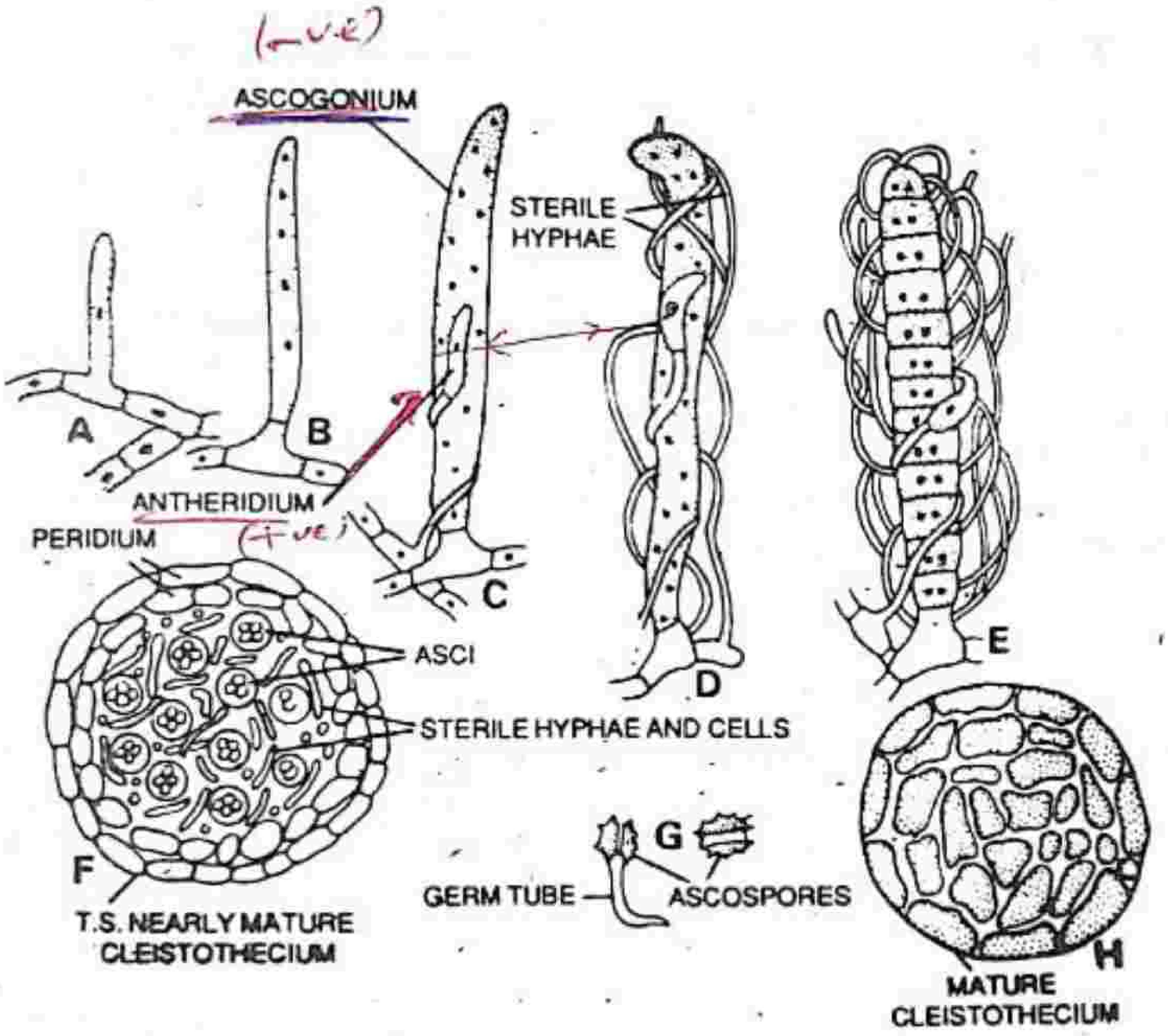


Fig. 5.14: Penicillium — Sexual Reproduction.

PHYLLACTINIA

Kingdom:	Fungi
Phylum:	Ascomycota
Class:	Leotiomycetes
Order:	Erysiphales
Family:	Erysiphaceae
Genus:	*Phyllactinia*
Species:	*P. guttata*

The Phyllactinia is an obligate endoparasite, causing powdery mildew in different hosts such as shisham (Dalbergia); amaltas (Cassia fistula); and shahtoot (Morus alba). On Dalbergia sissoo (shisham) white powdery mass is present on the lower surface of the leaf. The young cleistothecia are attached to the surface of the leaves. The cleistothecia are orange to yellow when young but later on as these mature become black. The leaves dry after the attack by the fungus and then fall on the ground.

Plant Body

The mycelium consists of a network of hyphae. The hyphae are septate, colourless, well branched, and abundantly present on the epidermis of infected parts of the host. Most of the hyphae are superficial. The fungus obtains nourishment by special hyphal branches. These branches enters the stomata and send haustoria into the mesophyll cells to obtain nourishment. The hyphal cells are uninucelate.

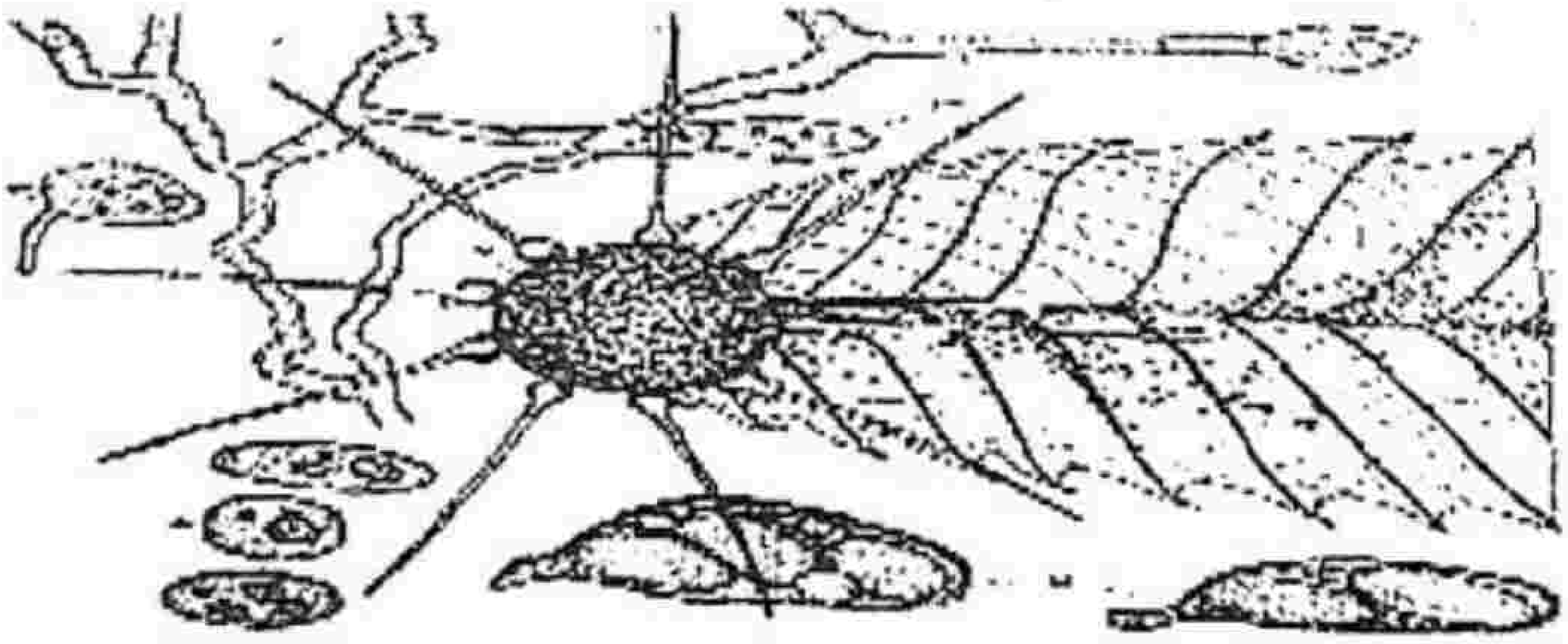


Fig. 5.15: Phyllactinia— A. An Infected Leaf; Mycelium and Conidiophores.

Reproduction

Phyllactinia reproduces asexually as well as sexually.

Asexual Reproduction

The fungus starts reproducing asexually by forming conidia a few days after the infection. The hyphae start producing long, erect, hyaline conidiophores. A conidiogenous cell at the apex of conidiophore produces conidia. The conidia fall off soon, therefore, the conidia are not produced in chains. The conidia are unicellular, colourless and clavate in shape. The conidia are dispersed by wind and germinate after falling on a host organ into new hyphae.

Sexual Reproduction

In late summer the conidial production slows down and stops finally, and sex organs start developing. The sexual branches are uninucleate and develop on different hyphae. The earlier stages of male and female branches are the same. A papillate outgrowth arise from the hypha, the nucleus of the hypha divides into two, one daughter nucleus migrates into the outgrowth, which is separated from the mother hypha by the formation of a septum. During the later part of development the female branch becomes stouter, curved, and anastomoses the developing male branch. The nucleus of the female branch divides and the division is followed by septum formation resulting in a stalk cell and a terminal ascogonium. The male branch remains erect and division of its nucleus and subsequent septum formation results in the formation of a stalk cell and a terminal antheridum. The nucleus of antheridium degenerates, therefore, the process of fertilization does not take place. The ascogonial nucleus divides and the ascogonium becomes binuceleate. Both the ascogonial nuclei divide and septa are laid down between the daughter nuclei in such a way that a three-celled filament is formed. The middle cell of this filament is binucleate and two cells present on its either side are uninucleate. Two nuclei present in the middle cell belong to different nuclei of the original pair present in the ascogonium.

Development of Ascocarp

In the meantime when the female branch has completed its development, sterile hyphae arise from the stalk cell of the female branch. These branches from the somatic hyphae present below it and development of the wall of ascocarp starts. From the basal uninucleate cell of the three-celled filament, hyphal filaments arise which form a layer lining the wall (peridium) of the young ascocarp. The ascocarp formed is globular and without an opening and is, therefore, a cleistothecium.

Asci Development

The middle binucleate cell of the three-celled filament elongates and its nuclei divide. Many ascogenou hyphae develop from the middle cell. The tip cells of these hyphae are uninucleate and the penultimate cells (last but one) are binucleate. These act as ascus mother cells and develop into an ascus. The nuclei fuse to form a diploid nucleus that undergoes meiotic division followed by a mitotic division to produce eight nuclei. Six of these eight nuclei degenerate and the remaining two develop into ascospores.

Structure of Cleistothecium

The cleistothecia are globular, orange to yellow in colour when young, but at maturity becomes black. The cleistothecia are provided with characteristics appendages which are rigid, spear-like, with a bulbous base and pointed tip. In addition to these appendages, the cleistothecia bear a crown of short, apical, gloeoid, branched appendages whose function is unknown, perhaps help the cleistothecia to stick to the substratum. The long bulbous appendages bend and lift the cleistothecia above the leaf surface. This helps in dissemination of ascospores effectively.

Dispersal of Spore

The asci open through an apical opening and the ascospores are released. These are carried away by wind and when fall on a suitable host germinate to form a new mycelium.

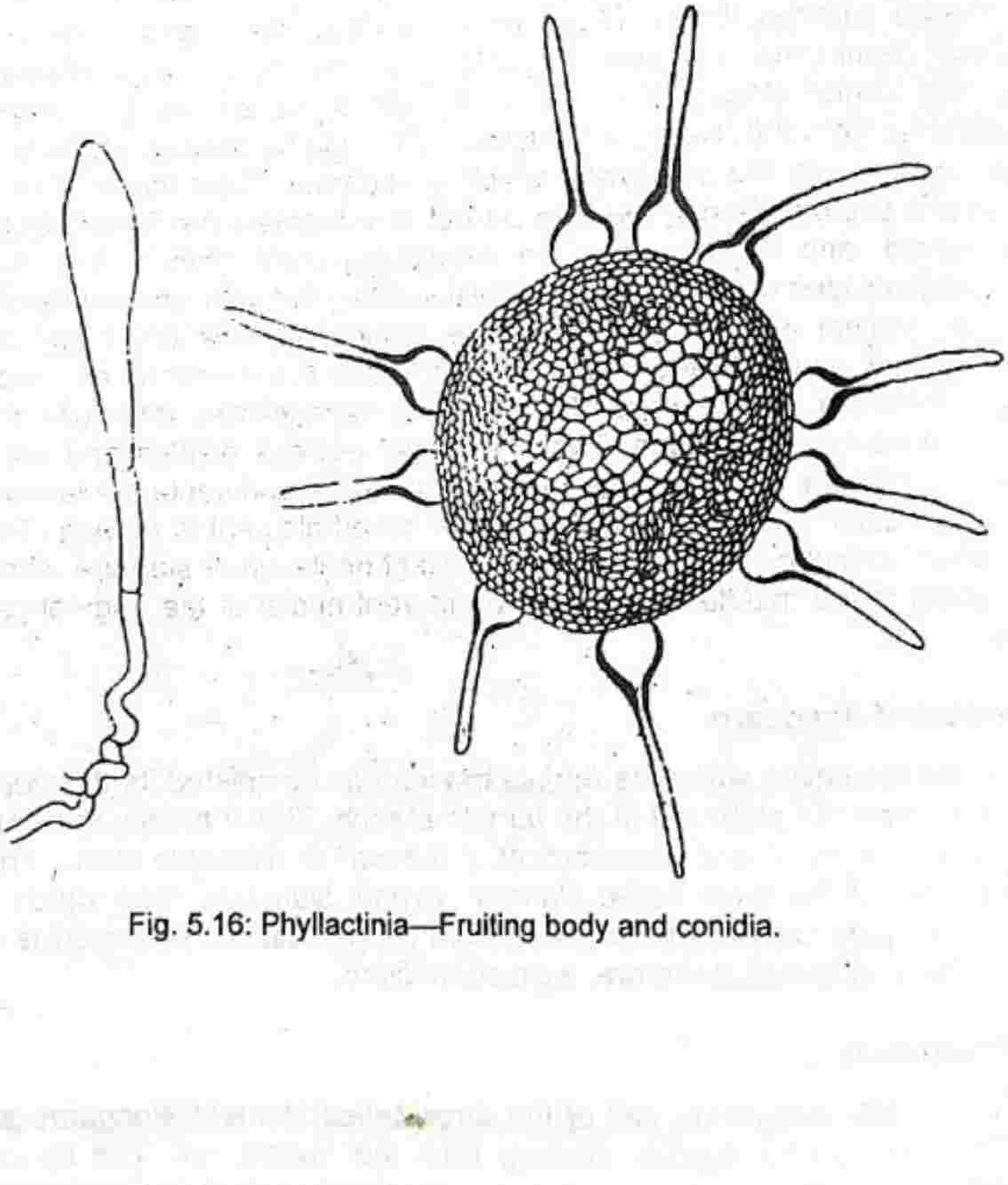


Fig. 5.16: Phyllactinia—Fruiting body and conidia.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Give characteristics of ascomycotina.
2. What is an ascus.
3. What is apothecium.
4. Define ascomycetes.
5. Describe budding in yeast.
6. Draw structure of penicillium.
7. How conidia are formed in penicillium.
8. Give asexual reproduction in phyllactinia.
9. What is an ascocarp.
10. What is phylogeny of ascomycetes.

B. Long Questions

1. Describe life cycle of yeast.
2. Describe structure and asexual reproduction in yeast..
3. Describe asexual reproduction in penicillium.
4. Describe sexual life cycle of penicillium.
5. Draw life cycle of phyllactinia.
6. Write note on fruiting bodies of ascomycetes.

BASIDIOMYCOTINA

The Basidiomycotina are fungi in which the perfect state spores are basidiospores and these are produced externally on basidia. The number of basidiospores is definite, usually four.

GENERAL ACCOUNT

1. The members are terrestrial and may be saprotrophic or parasites. The saproptrophic species are found on wood, litter, dung, and wet leaves. The parasitic species are found on many angiospermic plants, especially the cereals (rusts and smuts), where these cause serious damages.
2. The mycelium consists of well developed, septate, microscopic hyphae that penetrate the substratum and absorb nourishment. The mycelium is variously coloured and often spread out in a fan-shaped growth. In some species, hyphae form thick strands, the rhizomorphs.
3. The hyphal wall is usually composed of microfibrils of chitin and glucans in a majority of basidiomycetes.
4. The hyphal cells contain all the typical cellular organelle.
5. The hyphae composing the mycelia in basidiomycetes are septate and the septa are characterized by presence of a pore that allows cytoplasmic continuity. The septum is characterized by a doughnut-like or barrel-shaped swelling in the center of the septal wall surrounding the central pore. Such a septum is called dolipore septum.
6. The mycelium may be primary, secondary or tertiary according to phases of development.

i.Primary Mycelium or Homokaryon

It develops from the germination of a basidiospore.

ii.Secondary Mycelium or Dikaryon

The primary mycelium gives rise to secondary mycelium. The development of secondary mycelium usually involves an interaction between two compatible homokaryotic mycelia. This phenomenon is called dikaryotization. The secondary mycelium shows centrifugal growth and forms basidiocarps each year.

iii.Tertiary Mycelium

The secondary mycelium forms complex tissues to produce sporophores or basidiocarps. This organized, specialized tissue is called tertiary mycelium.

Dikaryotization

The development of secondary mycelium usually by the interaction between two compatible homokaryotic mycelia is called dikaryotization. It can be brought by fusion of two uninucleate cells of the compatible homokaryotic mycelia that results in the formation of a binucleate cell (dikaryon).

Clamp Connections

It is a mechanism found in many basidiomycetes. The basic aim is to insure that sister nuclei arising from division of the dikaryon become separated into two daughter cells.

A clamp connection begins as a short branch from an end cell of a growing hypha and forms a bent hook, the tip of which connects with the cell wall near the septum. As the walls between the clamp and cell dissolve, the nuclei divide, one division is so oriented that one of its daughter nuclei is formed in clamp and the other in the mother cell. The other division is oriented horizontally in the mother cell. The daughter nucleus in the clamp then migrates into the mother cell and the two septa are formed, one cutting off the clamp from its mother cell, and the other vertically just below the point where the clamp fused with the cell wall of its mother cell. Thus, the mother cell has divided into two cells while the dikaryotic condition is perpetuated, with nuclei of different mating types always present in the newly formed cells as the hypha grows.

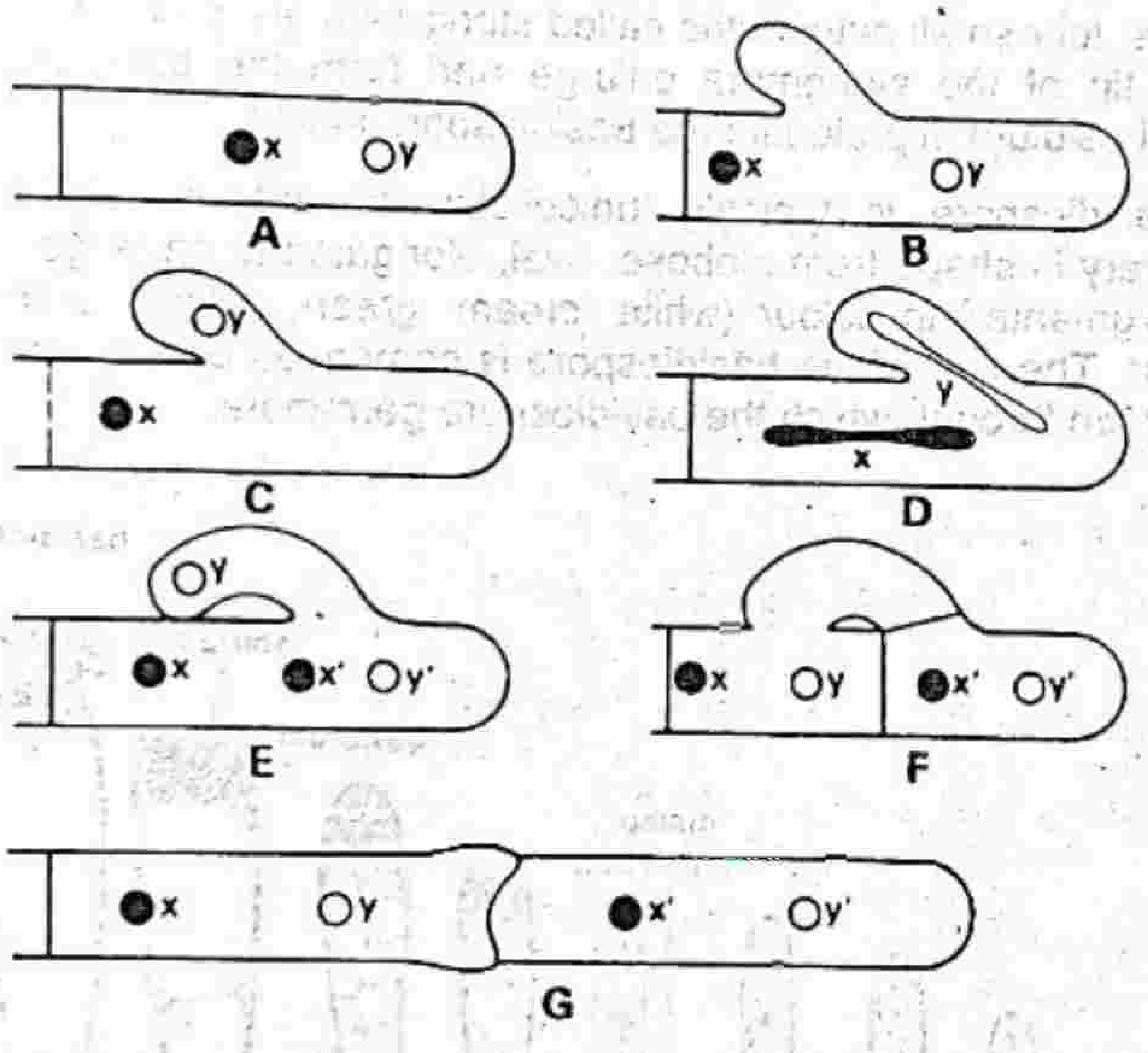


Fig. 5.17: Successive stages during formation of clamp connections.

Reproduction

The basidiomycotes reproduce by vegetative, asexual and sexual ways of reproduction.

Vegetative Reproduction

The vegetative means of reproduction are budding (basidiomycetous yeasts), and fragmentation of mycelium.

Asexual Reproduction

Asexual reproduction is either by formation of conidia, arthrospores or oidia.

Sexual Reproduction

The sex organs are absent in most of the basidiomycetes and are known only in Uredinales (rusts). These are not very well developed in rusts as well, and are represented by spermatia and receptive hyphae. However the plasmogamy, karyogamy and meiosis, do take place in all the basidiomycetes. The plasmogamy takes place by various methods and results in dikaryotization, the karyogamy and meiosis occur in basidia.

Basidium and Basidiospores

The basidium is the organ in which karyogamy and meiosis takes place in basidiomycotina, as a result of which generally four basidiopsores are produced on the surface of the basidium. A typical basidium is club-shaped and originates as a terminal cell of a binucleate hypha which becomes separated from the rest of the hypha by a septum over which a clamp connection is generally found. The two nuclei within the basidium fuse and the fusion nucleus undergoes meiosis to produce four haploid nuclei. In the meantime, four small outgrowths called sterigmata are pushed out at the top of the basidium. The tip of the sterigmata enlarge and form the basidiospore initials. The contents of the basidium migrate into the basidiospore initials.

The basidiospore is typically unicellular, uniucleate haploid structure. The basidiospores vary in shape from globose, oval, elongated to sausage-shaped; and from colourless to pigmented in colour (white, cream, green, yellow, orange, pink, brown, purple, or black). The wall of the basidiospore is composed of five wall layers and have germ pores in them through which the basidiospore germinate.

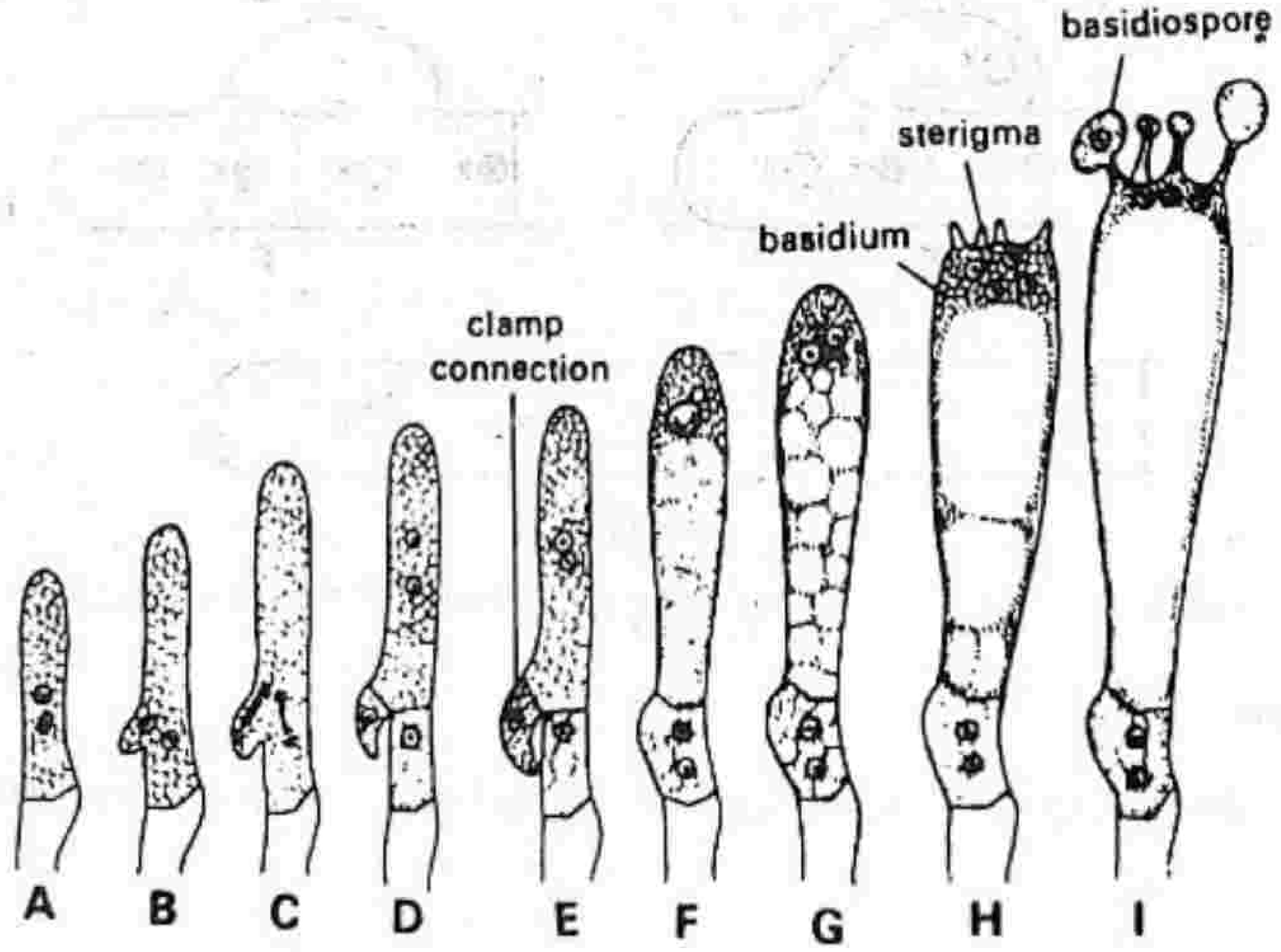


Fig. 5.18: Successive stages during development of a Holobasidium.

Basidiocarps

The basidiomycetes produce their basidia in highly organized fruiting bodies, the basidiocarps. The basidiocarps vary in size from microscopic to a meter or more in diameter. The basidiocarps may be openor remain permanently closed. The spores are liberated on disintegration of basidiocarps where these are closed. The mushrooms, shelf-fungi, coral fungi, puffballs, earthstars, stinkhorns and bird-nests fungi, all are basidiocarps. The basidia are formed in definite layers called hymenia. The basidia may contain sterile elements which may be basidioles or cystidia which are larger in size and protrude beyond the other hymenial elements. Both these structures are sterile and provide support for the fertile basidia.

USTILAGO

Taxonomic Position

Kingdom:	Fungi
Division:	Amastigomycotins
Sub-Division:	Basidiomycotina
Class:	Basidiomycetes
Order:	Ustilaginales
Family:	Ustilaginaceae
Genus:	Ustilago
Species:	*U. triticci*

Ustilago is a genus of smut fungi. It is afacultative parasite and cause a disease called as smut. The genus claims 400 species. Its various species attack the ovaries of grasses, some times destroying the whole ears and producing a black powdery mass of spores. All species of the genus complete their life cycle on the host and is thus called as autoecious parasite. Ustilago is very common in our country and its various species attacking the wheat, maiz, corn, oat and barly.

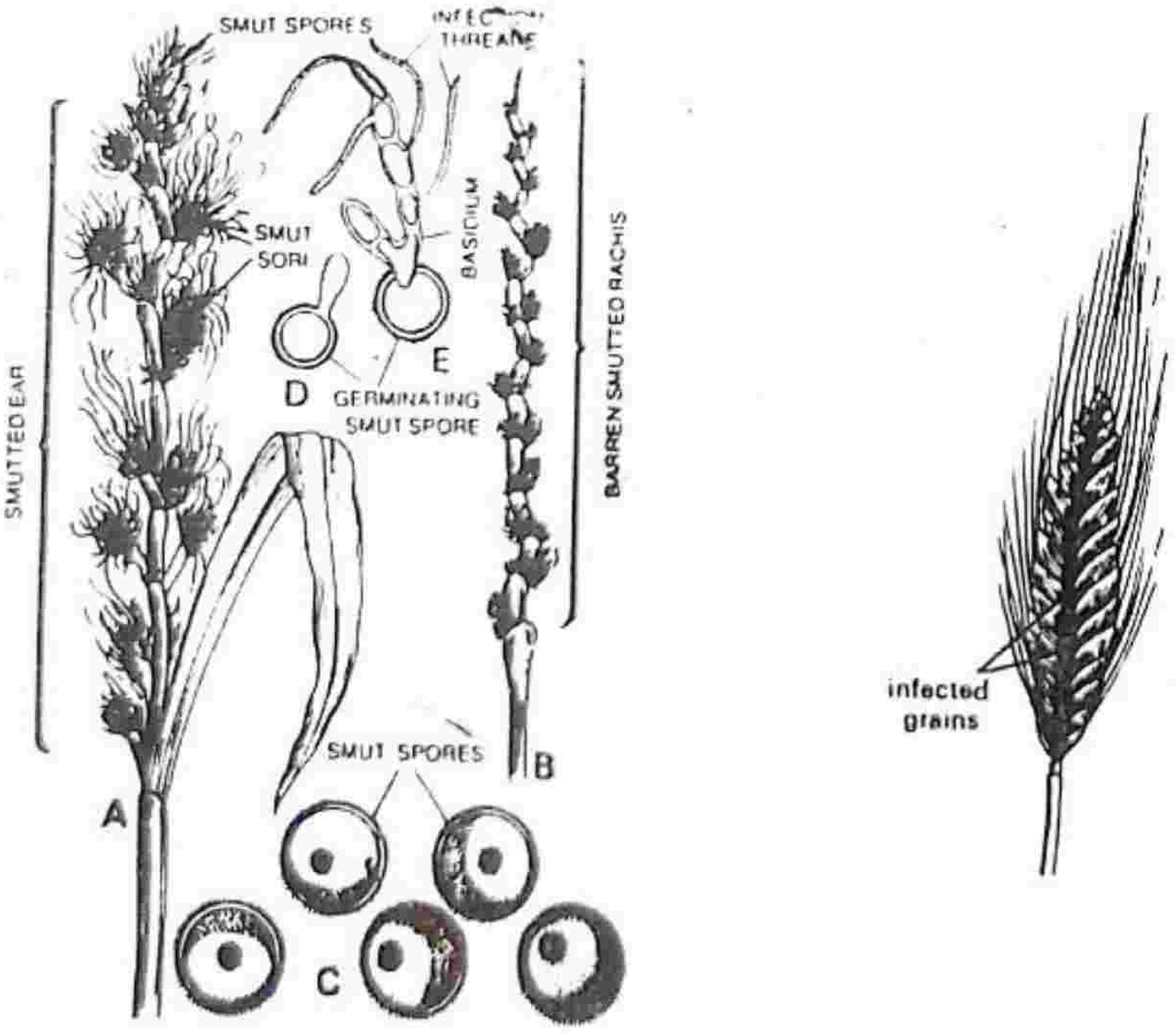


Fig. 5.19: Loose smut of wheat.

The disease makes its appearance when the ear are produced. The ears in the diseases plants emerges earlier than the healthy plants. All flowers are replaced by black powdery mass of spores. These spores are called as chlamydospore or teleuto spores. In the young spikelets the spores are covered by a slivery membrane, which burst before emergence of ears. When the spores are blown off, only the central axis of the inflorescence is left behind.

The disease is seed born. The dikaryotic hyphae of the fungus are present in the seed. When the infected seeds are sown, the embryo starts germination, the dormant mycelium also become active and keep on growing in the apical meristem without causing harm to the plant. When the ears are produced, the mycelium enters the flower primordial and ultimately forms a mass of hyphae in the ovaries of young flower. The mass of hyphae consists of short cells, which are binucleated.

The wall of each cell gelatinized and its protoplast secretes a thick wall around itself and is transformed into spore. These spores are produced in such a large number that whole inflorescence become transformed into a black powdery mass around the central axis. The spores are called as chlamadospores or teleotospores. Each spore is unicellular and binucleate. The wall of spore is very thick and its surface is variously sculptured. The thick spore wall is differentiated into two layer. The outer wall or exosporium is thick while the intine is always thin.

Dispersal of spores

The spores are dry and are dispersed by wind, insects or by water. They are logged on the ears of healthy plants.

Germination of spores

The spores do not function as resting spores. They fall on the stigma of flower and germinate to infect the new born ears. The optimum temperature for germination ranges from 20-30°C. Before germination, the two nuclei fuses with each other to produce a diploid zygotic nucleus (Synkaryon). The zygotic nucleus undergo reduction division. In the mean time a short germ tube of pro-mycelium is produced. The promycelium is also called epibasidium or metabasidium.The four haploid nuclei formed as results of meiosis are migrated to the promycelium. These are called as primary mycelium. The myceliumconsists of hyaline, transversely septate producing four cells. Since the segregation of the sexual stage takes placeduring meiosis two of these nuclei are of plus strain and two of minus strain.

In *Ustilago tritici*, the promycelium germinate to produce the hyphae directly. Which is then conjugated to produce the dikaryotic hyphae. No basidiospores are produced.

Infection

The diplophasic mycelium infects the ovaries, grow intercellularly, and ultimately invade the embryo. The mycelium after establishment in the embryo becomes dormant without causing damage to the embryo. The infected seeds are as healthy as the uninfected one.

The Smut Fungi

Economically the smuts are very important causing smut diseases to food crops as well as to ornamentals resulting in losses worth millions.The smut diseases are of two types.

i.Loose Smut

In loose smut the spores are not covered by any membranous structure. They are directly exposed to the air at the time of flowering and can be easily disseminated by wind, e. g., in loose smut of wheat, oat and doob-grass.

ii.Covered Smut

In covered smut the spores remain enclosed by a membranous covering of the grain. Mature spores are not directly exposed to the air and cannot be disseminated by wind. They are liberated only when the wall of the grain is broken, e. g., in covered smut of barley and sugar-cane.

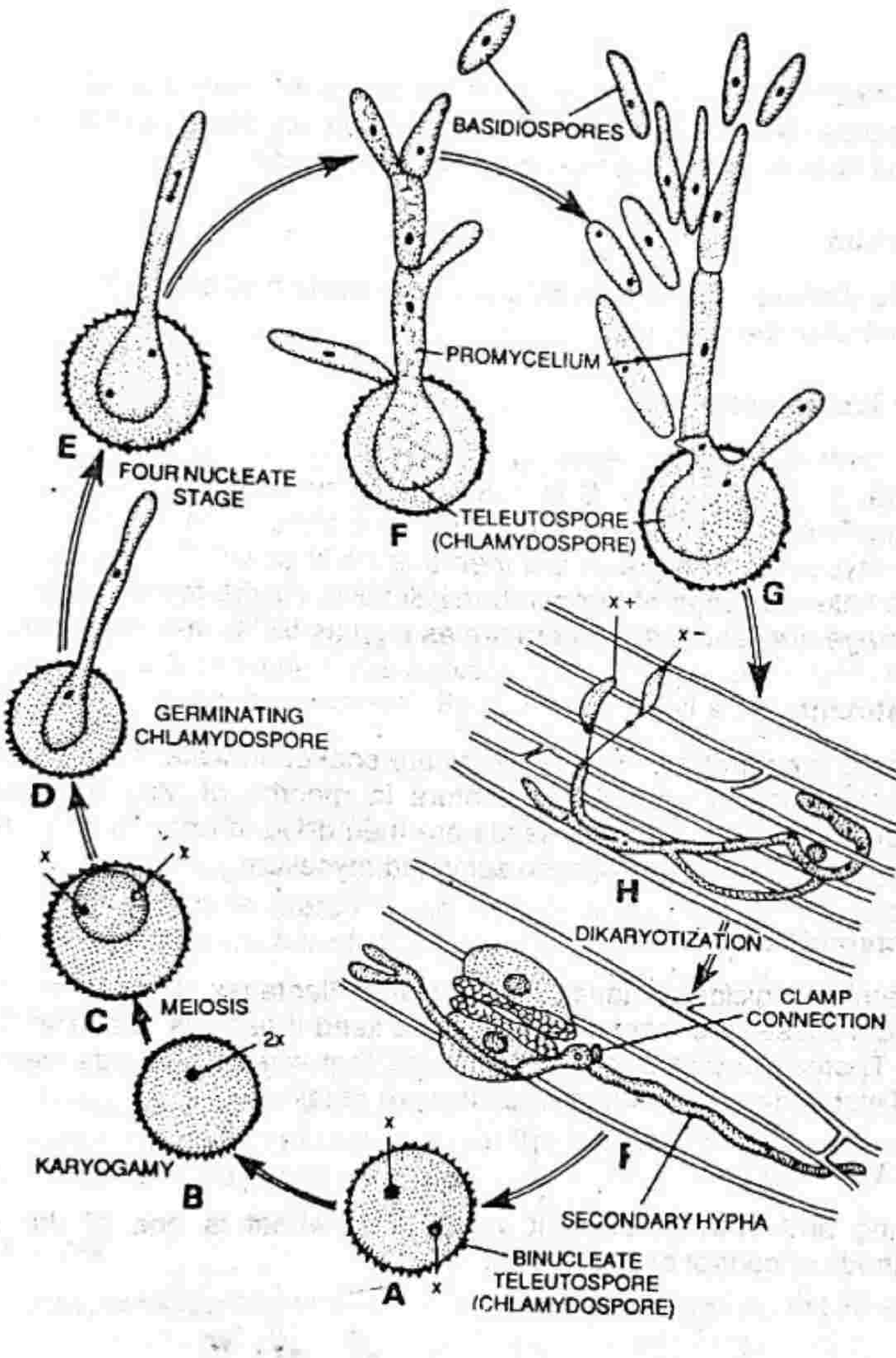


Fig. 5.20: Loose smut of wheat.Life Cycle.

CONTROL OF DISEASE

Various methods applied to control the disease are as followings:

i.Rogueing

The infected plants must be uprooted and burnt taking outside the fields. This method is practicable as the infected ears emerge earlier than the healthy ones and their destruction will help in controlling the spread of the disease.

ii.Seed Selection

As the disease is seed borne, a careful selection of seeds from a healthier crop will help in control of the disease.

iii.Hot Water Treatment

This method involves soaking of seeds for 4-5 hours in water at normal temperature ranging from 26-30 °C in order to activate the dormant mycelium. Then the seeds are transferred to hot water having a temperature of 54 °C for ten minutes to kill the activated mycelium. The grains are then dried and sown. This method requires strict vigilance as a little low range of temperature will fail to kill the mycelium and a high range may also damage the seeds. A temperature as high as 56 °C may damage the embryo.

iv.Solar Treatment

During this control method the seeds are soaked in water from 8 a.m. to 12 noon (for about four hours) at normal temperature in months of May and June. This will activate the dormant mycelium. The seeds are then dried in open sun in very thin layers for about four hours. The drying kills the activated mycelium.

v.Use of Systemic Fungicides

Systemic fungicides Vitavax (D 735) and Plantavax (F 461) much effective in controlling the disease when these were used as seed dressings at a rate of 2.5 gms. per kg. Similarly Thomas and Chatrath (1975) found that when the seeds were treated with 0.1 to 0.2% Thiabendazole, excellent results were obtained.

vi.Resistant Varieties

Raising and sowing resistant varieties of wheat is one of the simplest and effective methods of control of the disease.

PUCCINIA GRAMINIS

L.Q

Taxonomic Position

Kingdom: Fungi
Division: Amastigomycotins
Sub-Division: Basidiomycotina
Class: Basidiomycetes
Order: Uredinales
Family: Pucciniaceae
Genus: *Puccinia*
Species: *P. graminis*

GenusPuccinia has many species which are obligate parasite on a wide variety of host. *Puccinia graminis tritici* is a common on wheat and also parasites on various species of grasses such as oat, barley, rye etc.

The fungus completed its life cycle on two different hosts and is called as heteroecious rust. Five stages, (Uridinial stage, Telial stage, Basidial stage, Pycenial stage and Asial stage)are present in the typical life cycle of puccinia. Uridinial and Telial stages is present on wheat plant while the Pycenial and Asial stages are present on the Barberry plant

LIFE CYCLE ON WHEAT PLANT

Puccinia graminis causes mostly the stem of wheat causing the black stem rust. The first sign appears early in March in the form of elongated, reddish brown granular postules or sori. These sori are called as uredosori.

1. Uredinial Stage

The uredospores are one celled, binucleated, some what globose, slightly thick walled spores. These spores are produced on the stalks. The spores exert pressure on the underlying epidermis causing break down of the host epidermis to form uredinia and the stage is called as uredinial stage.

Dispersal of spores

The uredospores are blown away by the wind and logged on the wheat plant.

Germination of spores

The spores germinate with in few hours after falling on the wheat plant. The spores are germinated by the formation of germ tube. The germ tube reaches the stomata and the tip swells into the vesicle called appresorium. The cytoplasm along with nuclei migrates into the appresorium, which is then cut off by the formation of septum. A very fine tube from the appresorium is then entering into the sub-stomatal chamber. Then hyphae are produced in all directions. The hyphae are branched, septate and each cell is binucleated. The growth of the hyphae are intercellular and get nourishment by sending club shaped historia in the cell.

Production of Uredospores

Numerous hyphae are produced underlying the epidermis and a crop of new uredospores are produced. The production of large number of spores exert pressure on the underlying epidermis and sorous is exposed and postules are formed. As the uredospores are produced on the dikaryotic mycelium and they again give rise the dikaryotic mycelim again, thus this stage is called as asexual stage. Several crops of uredospores are produced throughout the season and in this way the disease spread to large number of plants rapidly.

2. Telial stage or Teleutospores

At the end of growing season, the color of uredosori changes from brownish to dark brownish to dark reddish or rusty. This color is due to the production of new spores called as tleuto spores. The tleutospores are two celled, binucleated, slightly oval and having thick wall. These spores are elongated or oval in shape with tapering end. Each cell of spore contains two nuclei and one germ pore.

Dispersal of Teleutospores

These spores are dispersed by wind and do not germinate immediately. They can with stand unfavorable condition and survive for a long period.

Basidial stage

On germination, each cell of the tleutospores produces germ tube called as promycelium or epibasidium. The two nuclei in each cell fuse together to form diploid nuclei. Four haploid nuclei are produced after meiosis. The cytoplasm along with nuclei migrates into the promycelium. The promycelium or epibasidium is then divided into four cells by the formation of transverse septa. Each cell contains only one nucleus. Each cell of the epibasidium produces a lateral ste·igma. The basidiospores are produced on the sterigma. Each basidiospore is one celled and mononuucleated. The basidiospores or sporidia are forcibly discharged and are dispersed by wind.

Life cycle on Barbary Plant

Basidiospores are not able to infect the wheat plant but they infect the alternative host*Berberis vulgaris*.

Germination of basidiospores

When the basidiospores lodged on the surface of leaf, they germinate by producing a short germination tube. The tube enters the epidermal cell. The hyphae grow in all direction and remify the mesophyll tissues. The hyphae are intercellular and obtained food by sending historia in the cell.

Pycnidial stage

The mycelium produced by the germination of basidiospores is monokaryotic. The hyphae of the monokaryotic mycelium form small knots just below the upper epidermis. These cells are then transformed into flask shaped cavities called pycnidia or spermatia. Each spermatia open to out side by a small aperture called as ostiole. Numerous small uninucleated spores called pycnedinspores are produced on short hyphae inside the spermatengia. Numerous paraphys·· come out of the ostiole and some of them act as receptive hyphae. The spermatia come out through the ostiole in a mucilage liquid. They are dispersed by insects.

Dikaryotization

When a spermatium becomes attached to the receptive hyphae of the opposite sexual phase, its nucleus enters the receptive hyphae of the opposite sexual phase. Spermatia of one sexual phase can fuse with the other phase.

Aecial Stage

In receptive hyphae the nucleus of the spermatium divides several time and the daughter nuclei migrate to the other nuclei. The dikaryotic cells form group of cells just below the lower epidermis. These binucleated cells divided transversely to form a chain of cells. Each cell of the chain divided into a larger and smaller cell. The larger cell is transformed into rounded spores called as aeciospore. Certain cells form wall around the spores to form peridium. As the spores are mature, the wall of the peridium ruptures and a cup shape structure called as acedium and aeciospore are released. The spores are dispersed by wind. Each spore is unicellular, binucleated and generally rounded in form.

Germination of Aeciospores

The aeciospore is not attack the barberry plant but they can only infect the wheat plant. They germinate on the surface of the wheat by producing a getrm tube. It infect the host through the stomata by the formation of apresorium. This infection results in the formation of dikaryotic mycelium in the host tissue. The uredospores are produced and the life cycle is completed.

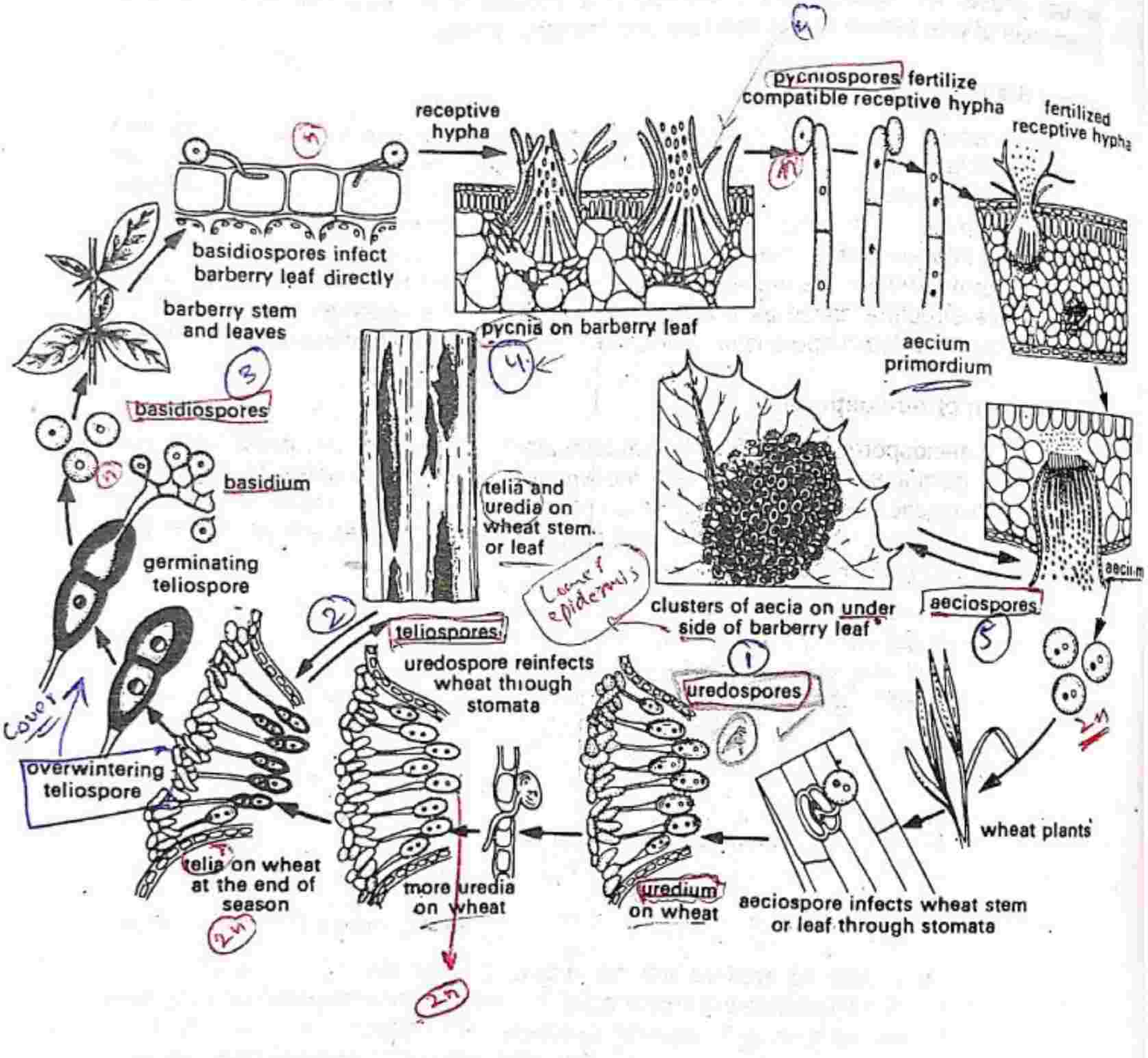

receptive hypha
pycniospores fertilize compatible receptive hypha
fertilized receptive hypha
basidiospores infect barberry leaf directly
barberry stem and leaves
pycnia on barberry leaf
aecium primordium
basidiospores
basidium
telia and uredia on wheat stem. or leaf
germinating teliospore
clusters of aecia on under side of barberry leaf
aecium
aeciospores
teliospores
uredospore reinfects wheat through stomata
uredospores
overwintering teliospore
wheat plants
telia on wheat at the end of season
more uredia on wheat
uredium on wheat
aeciospore infects wheat stem or leaf through stomata
Lower epidermis
Cover
1
2
3
4
5
2n
n

Fig. 5.21: Life Cycle of Puccinia graminis tritici

AGARICUS

Taxonomic Position

Kingdom: Fungi
Division: Amastigomycotins
Sub-Division: Basidiomycotina => form => basidocarp => sexual Rep.
Class: Holobasidiomycetidae
Order: Agaricales
Family: Agaricaceae
Genus: Agaricus
Species: *A. compestrus*

No description present

Agaricus species are commonly called meadow mushrooms since these are typically found in open, well manured, and quite often grassy areas. The genus contains some of the fine edible mushrooms including *Agaricus campestris and Agaricus bisporus.*

Agaricus Campestris

Agaricus campestris (L. campester=relating to plain or flat field) is common, wild, edible and cosmopolitan species. It grows on damp and dead organic substances such as humus, horse dung, damp rotten wooden logs, tree trunks and meadows rich in decaying organic matter.

PLANT BODY

The plant body of the fungus can be divided into two main parts, the vegetative mycelium and basidiocarp formed of hyphae as result of sexual reproduction. The basidiocarp is usually called a mushroom.

Vegetative Mycelium

The mycelium may be:

i. Primary Mycelium:

It is monokaryotic, short-lived and develops from germination of a basidiospore. The hyphae are septate and hyaline. The cells are short and contain oil globules, vacuoles and thin protoplasm.

ii. Secondary Mycelium:

The secondary mycelium is dikaryotic and arise by dikaryotization through somatogamy of two compatible monokaryotic hyphae. The hyphae composing secondary mycelium are long, branched, septate and have short cells. Typical dolipore septa are present between the adjacent cells. The secondary mycelium is more abundant, perennating, and produce mushrooms year after year.

iii. Tertiary Mycelium:

The mycelium producing basidiocarps or mushrooms is sometimes referred to as tertiary mycelium. It forms complex tissue which produce basidia.

The mycelium forms microscopic, thick, tangled, wooly masses called spawns.

Reproduction

The fungus reproduces sexually usually. The definite sex organs are absent, and the plasmogamy is brought about by fusion of two compatible somatic hyphae which results in the formation of a dikaryon. The nuclei of the dikaryon undergo conjugate divisions with that of the dikaryon to produce dikaryotic secondary mycelium. The basidiocarps develop from the hyphae of subterranean, perennial secondary mycelium.

Basidiocarp —A Mushroom

The aerial part of the fungus is the fruiting body (basidiocarp) of the fungus and is popularly known as mushroom.

Structure of Basidiocarp

A mushroom is umbrella-shaped generally. The upper portion, called pileus or cap, is circular and expanded. In a young condition the pileus is more or less button-like in shape and is completely enclosed by a thin whitish membrane called velum. The pileus

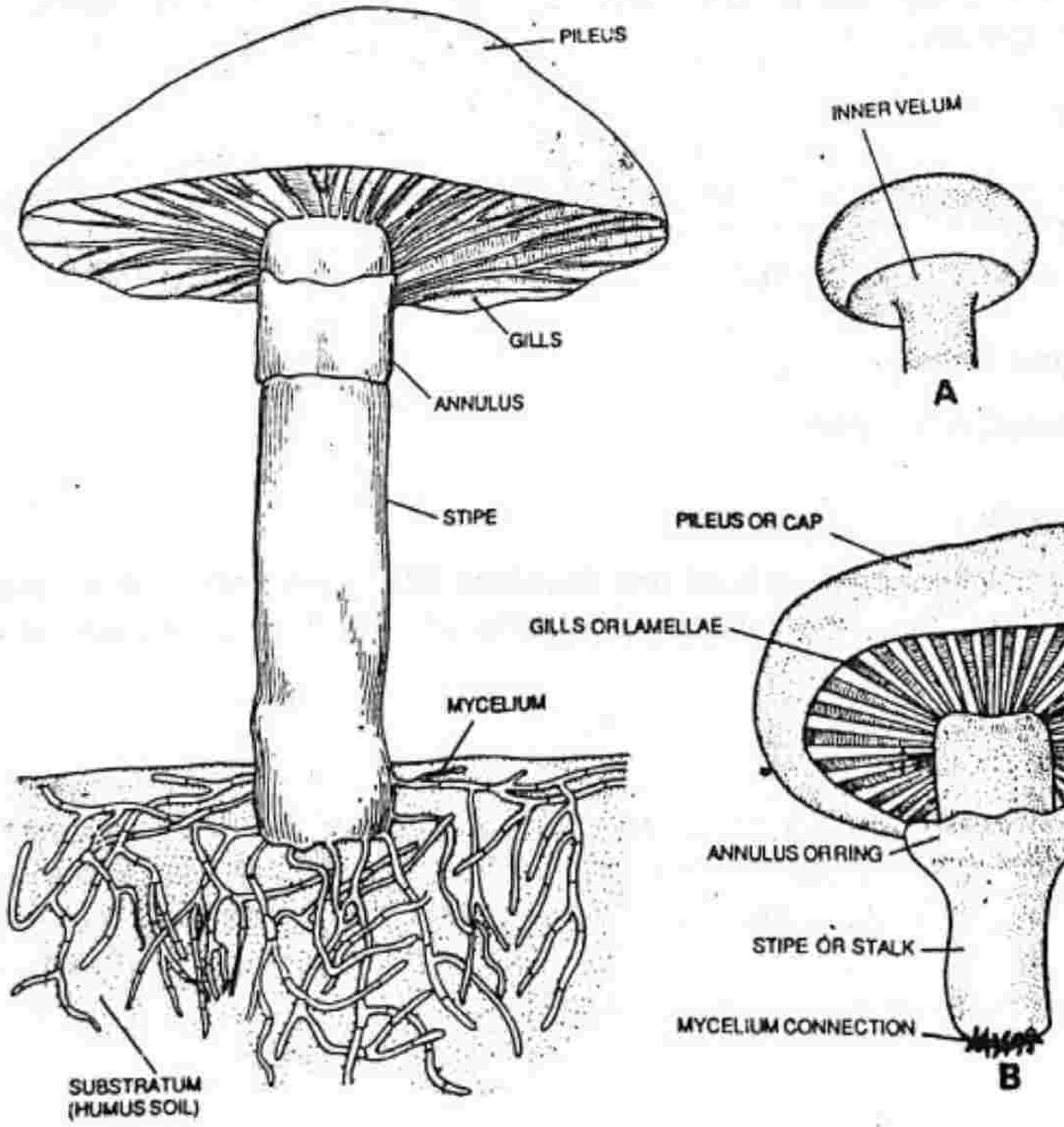


Fig. 5.22: A Basidiocarp.

is borne on a fleshy, pinkish-white, stalk called the stipe. As the pileus grows in size, the velum ruptures and its remnants surround the stipe to form annulus. A cavity is present under the pileus in which a large number of thin, vertical, platelike structures called lamellae or gills run out towards the edge of the pileus. Basidiospores develop on both surfaces of these lamellae. The gills are first pinkish but as the spores mature become dark brown in colour.

Development of Basidiocarp

The development of the basidiocarp starts as a tiny swelling consisting of a knot of the subterranean hyphae of secondary dikaryotic mycelium. This swelling enlarges into a broadly ovoid structure, the basidiocarp primordium. Later there is differentiation of a transverse internal ring of vertical hyphae followed by development of a ring-shaped cavity, the prelamellar chamber. The portion of the primordium above the prelamellar cavity finally develops into the pileus, that below into the stipe.

The tissue adjoining the upper side of the prelamellar cavity becomes differentiated into alternate radial bonds of slow- and fast-dividing cells. Each band of fast-dividing cells act as lamellar primodium, that soon projects downward into the prelamellar cavity. The diameter of the pileus increases greatly after the lamellae begin to develop. This results in formation of spaces between the lamellae. This stage of the basidiocarp is called button stage, and the edges of the pileus are joined to the stipe through a thin sheet of tissue, the velum.

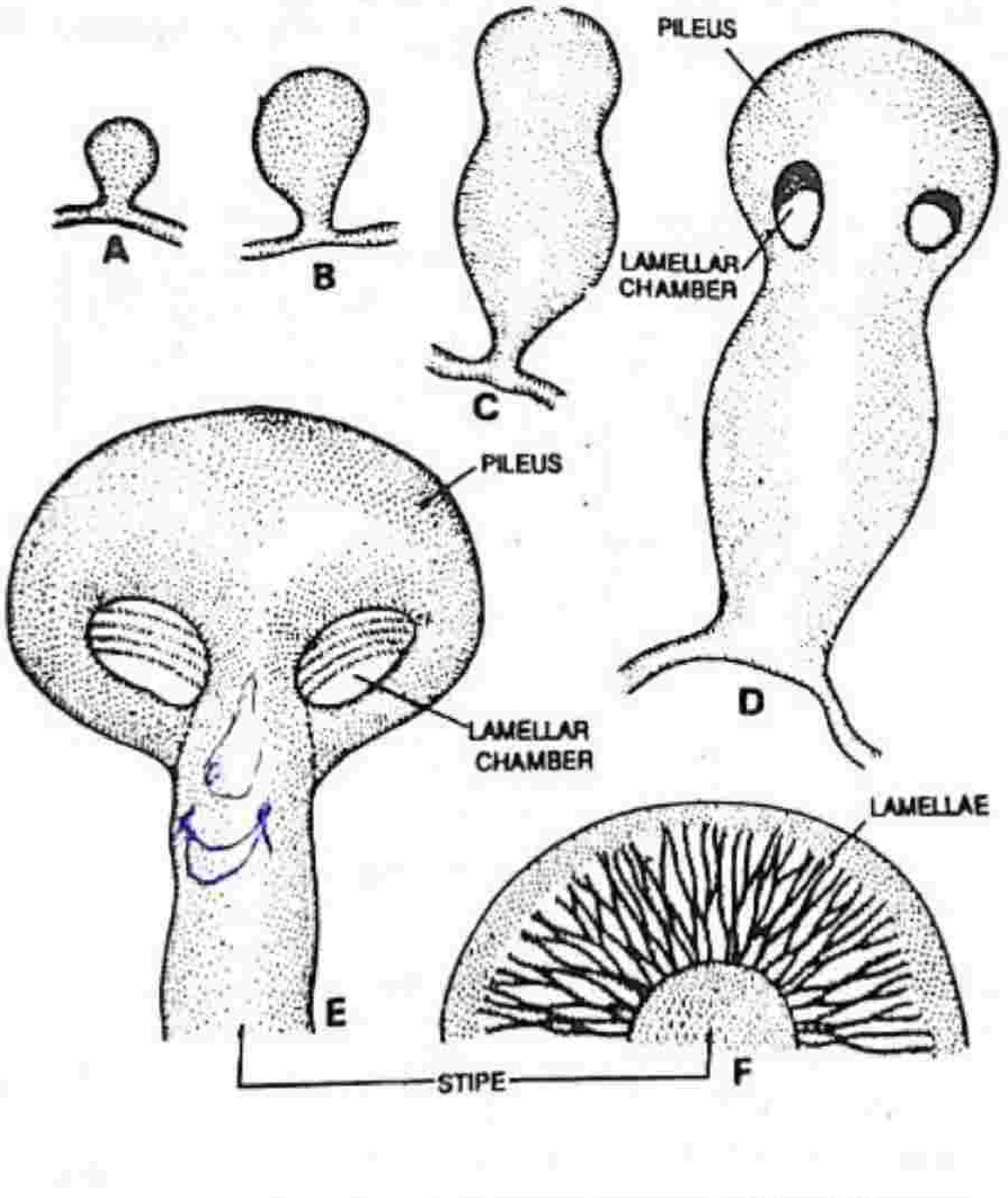


Fig. 5.23: Successive stages of development of basidiocarp.

Internal Structure of Basidiocarp

The basidiocarp is composed of interwoven hyphae which run parallel to each other in stipe region and are compactly arranged to form a pseudoparenchymatous tissue in the pileus region. In stipe the central hyphae are loosely arranged, with prominent air spaces, forming the medulla. whereas the outer hyphae constitute the cortex. The pileus also shows similar arrangement of hyphae into central medulla and outer cortex. Some of the hyphae of pileus develop into lamellae or gills.

Structure of a Lamella

Each lamella consists of three tissues:

i. Hymenium:

It is the fertile region of the lamella and consists of club-shaped, binucleate cells, forming a palisade-like layer on both sides of the lamella. All the cells of hymenial layer are not fertile, some of these develop into basidia, others into sterile paraphyses, and still others into elongated cystidia that protrude beyond the paraphyses.

ii. Trama:

Internal to the hymenium, there is a region of multinucleate elongate cells which extend from the hyphae of the pileus, the trama. The hyphae are so oriented that their long axes lie parallel to the hymenium.

iii. Sub-hymenium:

In between the hymenium and trama is a region composed of hyphae arranged at right angles to those of trama. The cells of these hyphae are isodiametric and binucleate.

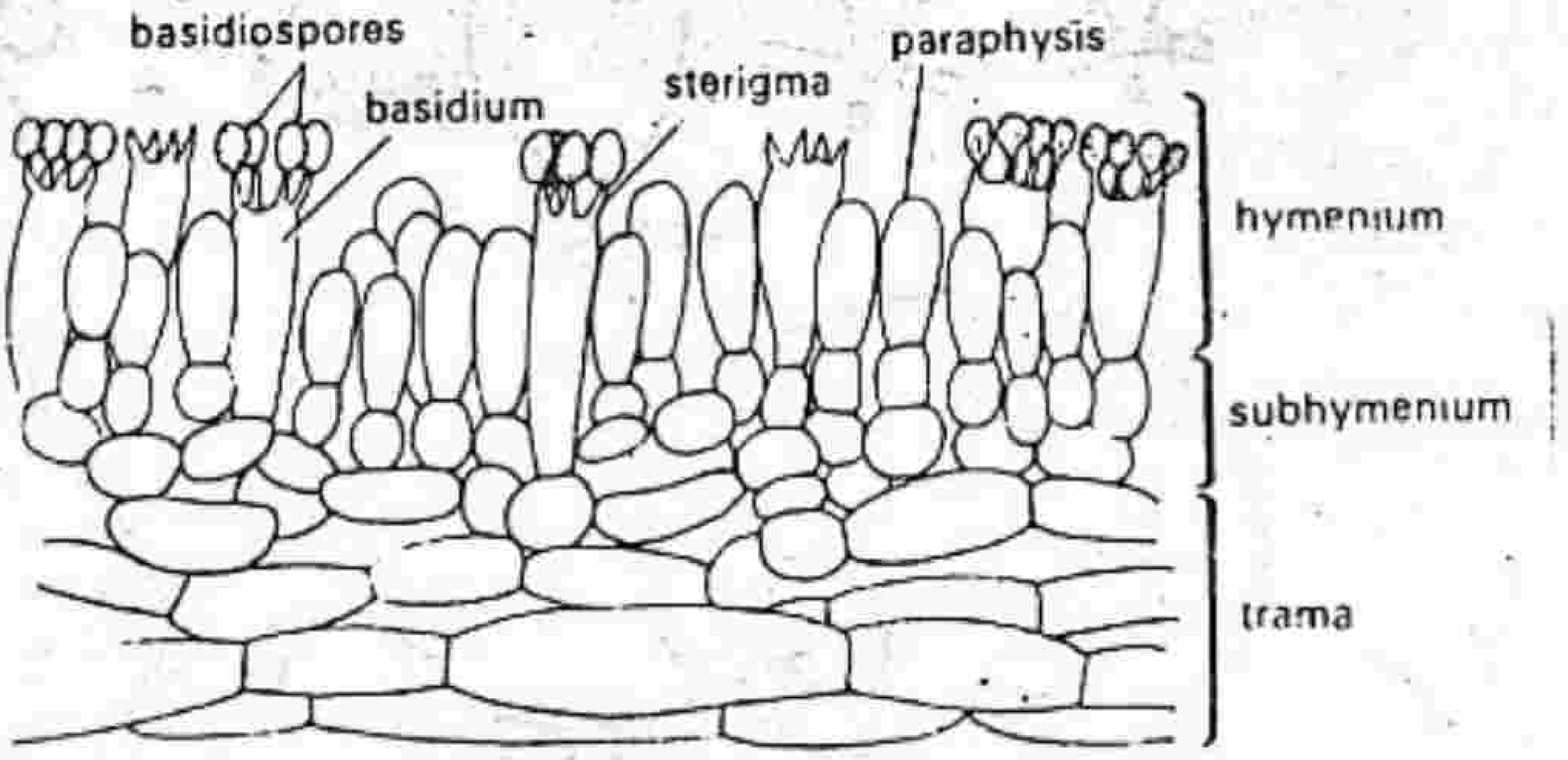


Fig. 5.24: T. S. of a lamella.

Development of Basidium and Basidiospores

A fertile cell of hymenial layer act as basidial initial. It enlarges in size to become a basidium. It is binucleate at first but as it enlarges, the two nuclei fuse (karyogamy). The zygote nucleus migrates to the apex of the basidium and undergoes meiosis to produce four haploid daughter nuclei. At the same time four peg-like outgrowth called sterigmata are produced at the apex of the basidium. The tip of each sterigma swells and one daughter nucleus migrates into. The sterigma is cut off from the basidium to become a basidiospore. Two basidiospores are of + strain and the other two of – strain.

A small lateral outgrowth called hilum develops at the junction of basidiospore and the sterigma. A small drop of liquid appears upon the hilum. This drop increases in size and when it reaches about 1/5th the size of the spore, the basidiospore shoot off from the sterigma alongwith the drop of liquid. The spores are discharged one by one at intervals. The basidiospore upon falling a suitable substratum germinates into primary mycelium of either strain (+ or -)

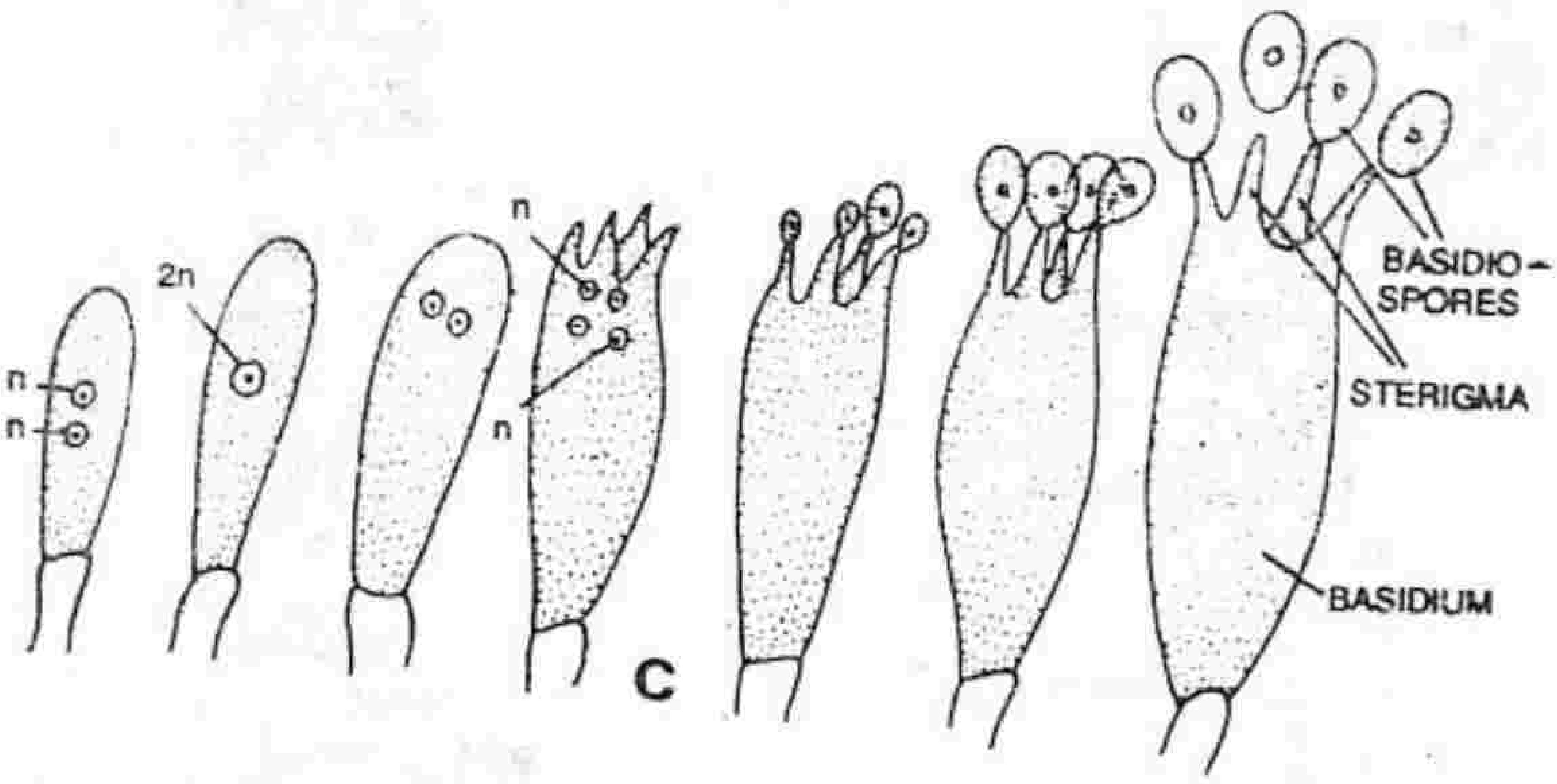


Fig. 5.25: Development of basidium and basidiospores.

Fairy Rings

Agarics produce rings called fairy rings in the grass. The best known of these are produced by *Marasmius oreades* which usually produces rings of dead or dying grass bordered on the outside and inside by darker, green, more vigorous grass. *Agaricus campestris* produces dark green rings in grass.

In these agarics the secondary mycelium has a tendency to grow in all directions from a central point forming a large, invisible circular colony. At the time of sporulation, the basidiocarps are produced at the periphery of the colony and thus form a ring. This ring is called a fairy ring, a name based on ancient belief that the ring marks the path of dancing fairies. The actively and profusely growing mycelium grows consumes available nitrogen and phosphorus in the humus leaving less nutrients for grass. The growth of the grass is retarded and grass plants either dry or become dead.

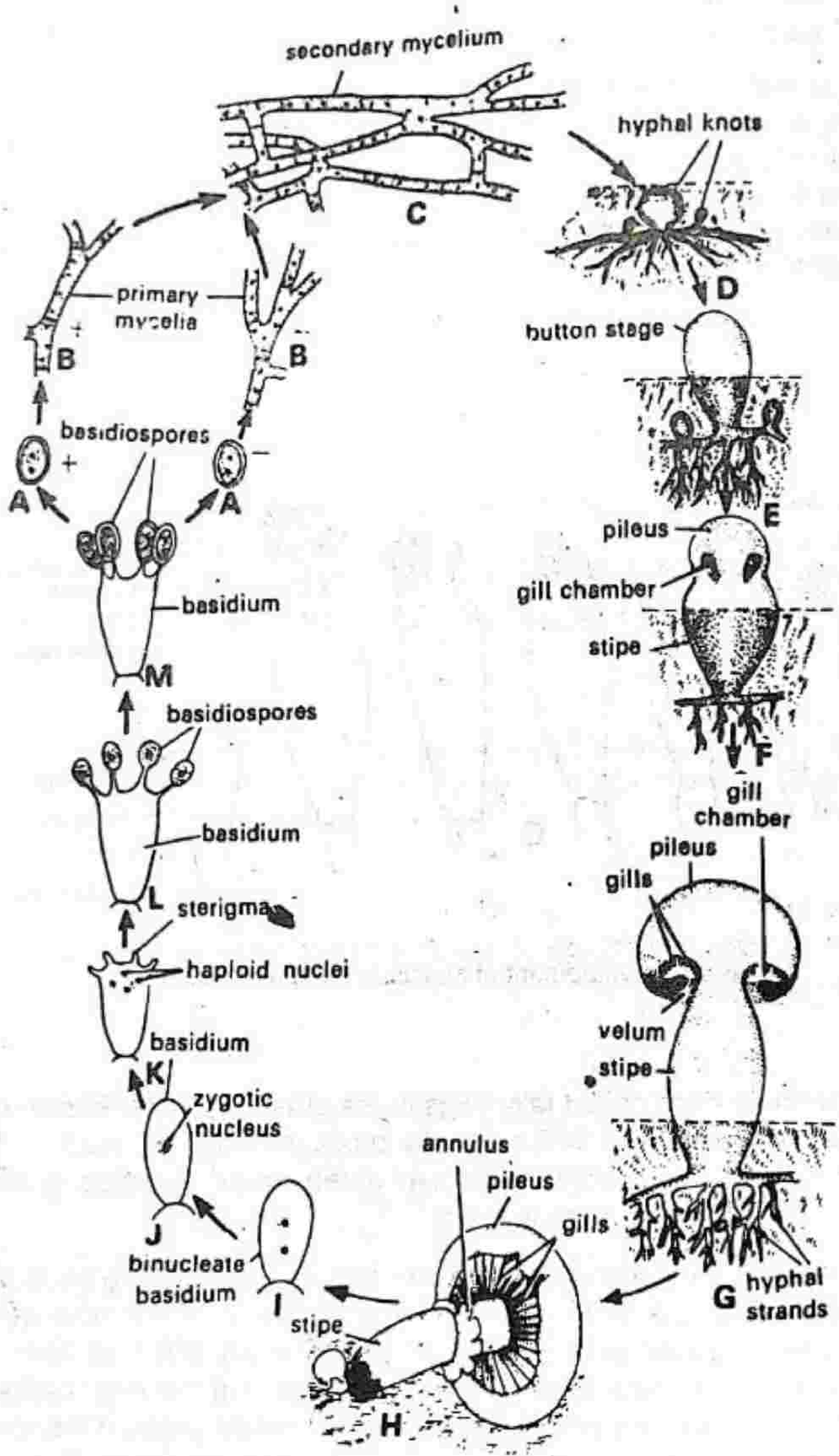


Fig. 5.26: Life cycle of a Mushroom.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Give characteristics of basidiomycotina.
2. What is a basidium.
3. What is a smut.
4. How many stages are found in rust.
5. Describe symptoms of smut.
6. Draw structure of aceium.
7. What is clamp connection.
8. What is dikaryotization.
9. What is basidiocarp.
10. Draw structure of mushroom.

B. Long Questions

1. Describe life cycle of smut.
2. What are the symptoms of smut also give its control measures.
3. Describe life cycle of rust.
4. Describe life cycle of rust on wheat plant.
5. Describe sexual stage of Puccinia.
6. Describe structure of agaricus.
7. Describe life cycle of agaricus.

DEUTEROMYCOTINA

Fungi Imperfecti

The sub-division is the second largest of the fungi and contains 1680 form-genera and over 17000 form-species. The sub-division is an artificial assemblage of fungi that have septate hyphae but reproduce only by means of conidia. Because of absence of perfect stage during their life cycle these are called fungi imperfecti.

GENERAL ACCOUNT

1. The members of this group are found vide variety of habitat. These may occur as powdery, wooly or blue-stained patches on the surface of wood, darkly stained regions of leaves.
2. These grow as saprobes or weak parasites of plants. A few are parasites on other fungi and some even trap and consume nematodes.
3. With the exception of unicellular yeast-like members all other deuteromycetes have a well developed intercellular or intracellular mycelium.
4. With the exception of unicelluar yeast-like deuteromycetes, which reproduce by budding, all others reproduce by conidia. In some genera, oidia and chlamydospores are also produced.

Parasexual Cycle

The deuteromycetes are characterized by the presence of a specific cycle, called parasexual cycle, in which plasmogamy, karyogamy, and haplodization take place, but not at a specified time or specific points in the life cycle of an organism.

The parasexual cycle exhibits heterokaryosis. It refers to a condition in which genetically different nuclei are associated in the same protoplast. It is the first step during parasexual cycle. The heterokaryosis can be brought about in several ways such as:

i. By anastomoses of somatic hyphae of different genetic constitutions;
ii. By mutation in one or more nuclei of a homokaryotic mycelium;
iii. By fusion of some of nuclei and their subsequent multiplication and spread among the haploid nuclei.

ALTERNARIA

Taxonomic Position

Kingdom: Fungi

Division: Amastigomycotins

Sub-Division: Deuteromycotina

Class: Deuteromycetes

Order: Moniliales

Family: Tuberculariaceae

Genus: Alternaria

Species: *A. solani*

Alternaria is a large genus of worldwide distribution. It occur as saprobes on dead and decaying organic materials, on seeds. They are responsible for causing leaf spot diseases of a number of economically important crop plants. The characteristics feature of the genus is production of obclavate or beaked, pigmented conidia with relatively thin transverse and longitudinal septa.

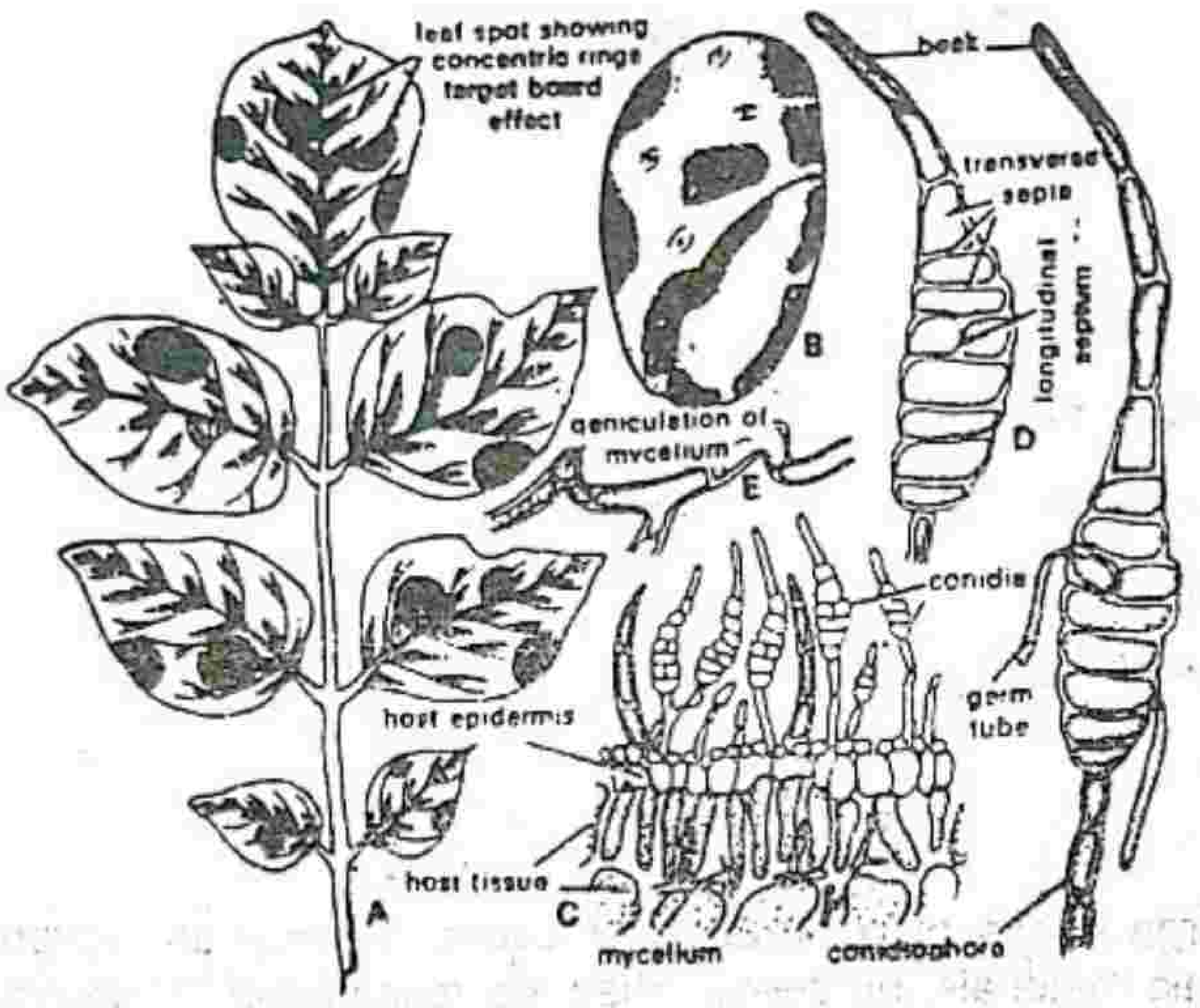
PLANT BODY

The mycelium consists of light-brown, slender, profusely branched, septate hyphae which are first intercellular but later on may become intracellular. The cells are usually multinucleate.

Reproduction

Alternaria reproduces by producing conidia.The conidia develop at the tips of short, dark coloured hyphae called conidiophores. These resemble somatic hyphae and cannot be differentiated. A conidium develops as an apical bud from the uppermost cell of the conidiophore. It enlarges and divides by a transverse septum that develops by annular ingrowth. The center of the septum is traversed by a pore which provides pathway for translocation of materials between the conidiogenous cell and the conidium. The conidium also produce buds that develop into new conidia resulting in a chain of conidia. Later on some conidia divide by formation of a longitudinal septum. Such conidia which are produced by transverse as well as longitudinal septa formation are called muriform or dictyospores.

A mature conidium is surrounded by a two-layered wall, the outer layer is pigmented and inner layer is hyaline. The conidia are disseminated by wind and in the presence of suitable temperature and moisture by putting five to ten germ tubes.



A. Affected Leaf; B. Affected Tuber; C. Section of infected Leaf; D. Conidium and its Germination; E. A Mycelium.

Fig. 5.27: Alternaria solani — Life Cycle.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Give characteristics of deuteromycotina.
2. What is parasexual life cycle.
3. What is taxanomic position of Alternaria.
4. Draw diagram of Alternaria.
5. Why deuteromyctes are called as fungi imperfecti.
6. What is the habitat of alternaria.

B. Long Questions

1. Describe life cycle of Alternaria.
2. Describe general account of deuteromycotina.

THE LICHENS

LICHENS

The lichens are an association consisting of a phycobiont (an algae) and a mycobiont (a fungus) growing together to form a plant body of recognizable structure and appearance.

There are about 18,000-20,000 known species of lichens.

GENERAL ACCOUNT OF LICHENS

Occurrence

Lichens are ubiquitous found in a variety of habitats and biological associations. These occur in a wide range of habitats from the Arctic to Antarctic and all regions in between. These are found exposed on bare rocks in the deserts (saxicolous), on bark of trees (corticolous), directly on wood (lignicolous), on ground (terricolous), on siliceous rocky shores of sea (marine), on hard siliceous rocks in freshwater (freshwater), on frozen substrata of polar regions.

Lichen Components

A lichen consists of algae (photobionts) and fungi (mycobionts).

Algal Components or Photobionts

About 24 species are involved in lichen formation. Most of these belong to the blue-green algae such as *Clothrix, Nostoc, Stigonema*; while the others are green algae like *Coccomyxa, Myremecia, Pseudotrebouxia, Trebouxia and Trentepohlia*. The algal components represent about 7 % of the total thallus volume and are usually limited to the sub-surface layer of the thallus. They reproduce usually by zoospores and aplanospores.

Fungal Components or Mycobionts

The great majority of fungal components belong to Ascomycotina. In few lichens basidiomycetes and deuteromycetes are the fungal partner.. The fungal partner is responsible for determining the lichen morphology as a whole in most of the lichens. The fungal components form the bulk of lichen thalli. These are arranged in such a way to form a network of hyphae in which the algal cells are embedded.

Morphology of Lichen Thallus

The body of a lichen is a thallus ranging from grey to greyish-green in colour. In some species the thallus may be yellow, red, orange or brown in colour.

On the basis of form, nature of attachment to the substratum and growth, the thalli can be classified into the following basic types:

i. Crustose

The thallus is thin, flat, crust-like and closely appressed to the substratum (trees, rocks or soil), e. g., in *Graphis, Verrucaria, Haematomma and Lecanora*. The lichens with crustose thalli appear as crusts and are associated with substratum so intimately that they cannot be separated from them.

ii.Foliose

The thallus is flat, leaf-like, lobed and branched. It is attached to the substratum with the help of attaching organs called rhizines, e. g., in *Physcia, Gryophora, Parmelia*, etc.

iii.Fruticose

The thallus is erect or pendent, cylindrical or branched. These are bush-like in appearance. These are attached to the substratum through basal portion composed of strands of densely packed hyphae. The common examples are Usnea, Bryoria etc.

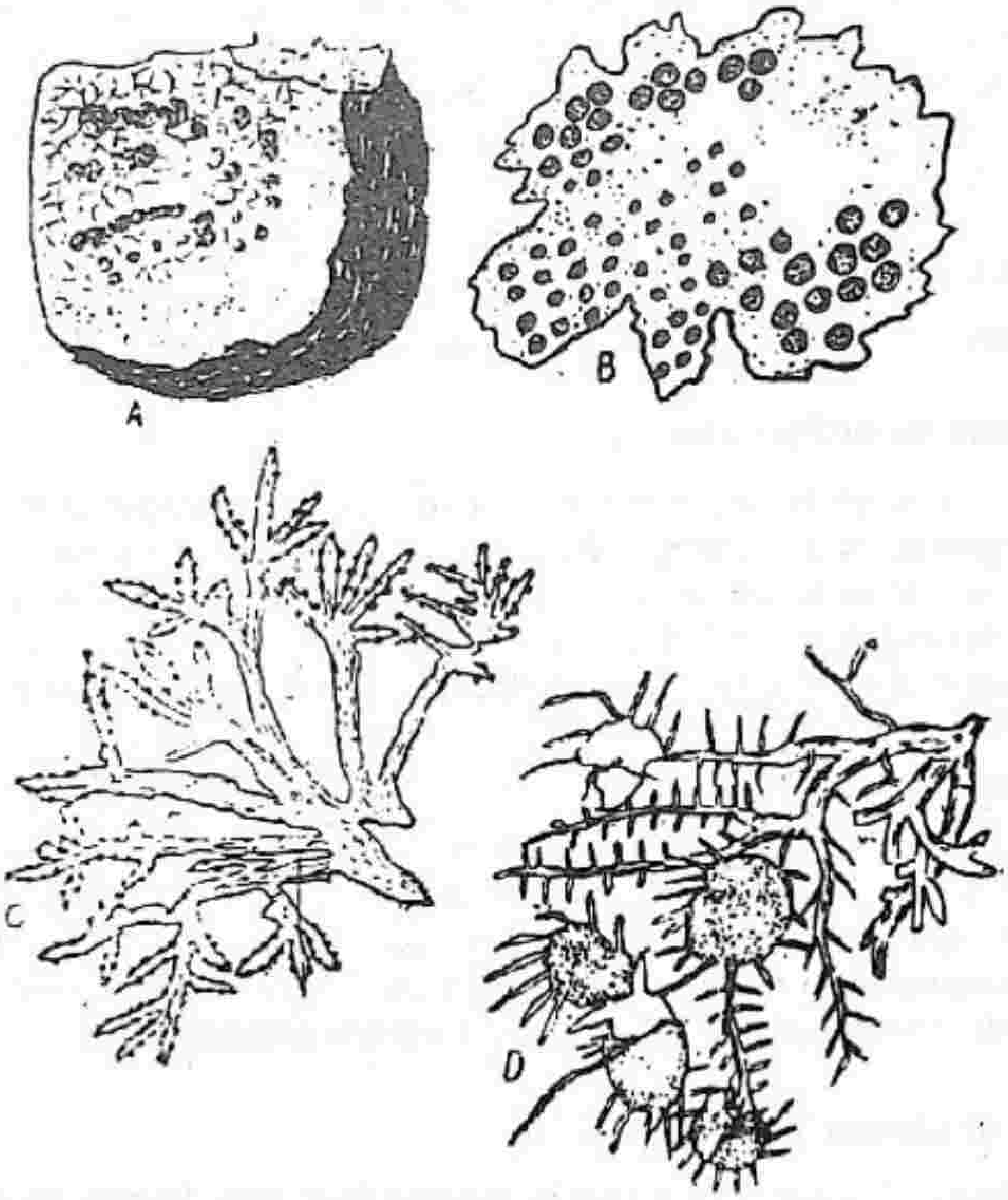


Fig. 5.28: Morphology and internal organization of lichen thalli.

Internal Structure of Thallus

On the basis of distribution of algal cells the lichen thalli are of two types.

i.Homiomerous

In these thalli the algal and fungal components are more or less evenly distributed throughout the thallus, e. g., in Collema. The algal component belong to blue-green algae. The fungal hyphae form a thin outer protective layer. Only a few lichens, mostly crustose, possess such thalli.

ii.Heteromerous

In these thalli the algal cells form a distinct layer, usually towards the upper side. The main bulk of the thallus is formed by fungal hyphae. The thalli of most foliose and fruticose lichens are heteromerous, e. g., Physcia, Parmelia, etc.

The following tissue zones can be recognized in a typical heteromerous thallus.

i. The Upper Cortex:

It is a dense layer formed of interwoven fungal hyphae which act as a protective and colloidal, water-retaining layer. The fungal hyphae are densely woven to form a parenchyma-like tissue (pseudoparenchyma) as in many lichens.

ii. Algal Layer:

Below the upper cortex, a distinct algal layer is present. The algal cells are either enveloped by the fungal hyphae or intermingled with them. The algae belong to either blue-green algae or green algae. This zone is photosynthetic.

iii. Medulla:

Just below the algal layer medulla or central portion of the thallus is present. It consists of loosely arranged hyphae which are either longitudinally oriented or interwoven to form a loose prosenchyma. These act as conducting cells. The medulla forms the main bulk of the lichen thallus.

iv. The Lower Cortex:

The lower surface is bounded by a dense layer of fungal hyphae constituting the lower cortex. These hyphae run either perpendicular or parallel to the surface of thallus.The rhizines, arise from the lower cortex and enter the substratum. They may conduct water rapidly in the capillary spaces among the component hyphae, but their primary role is to anchor the lichen to the substrate.

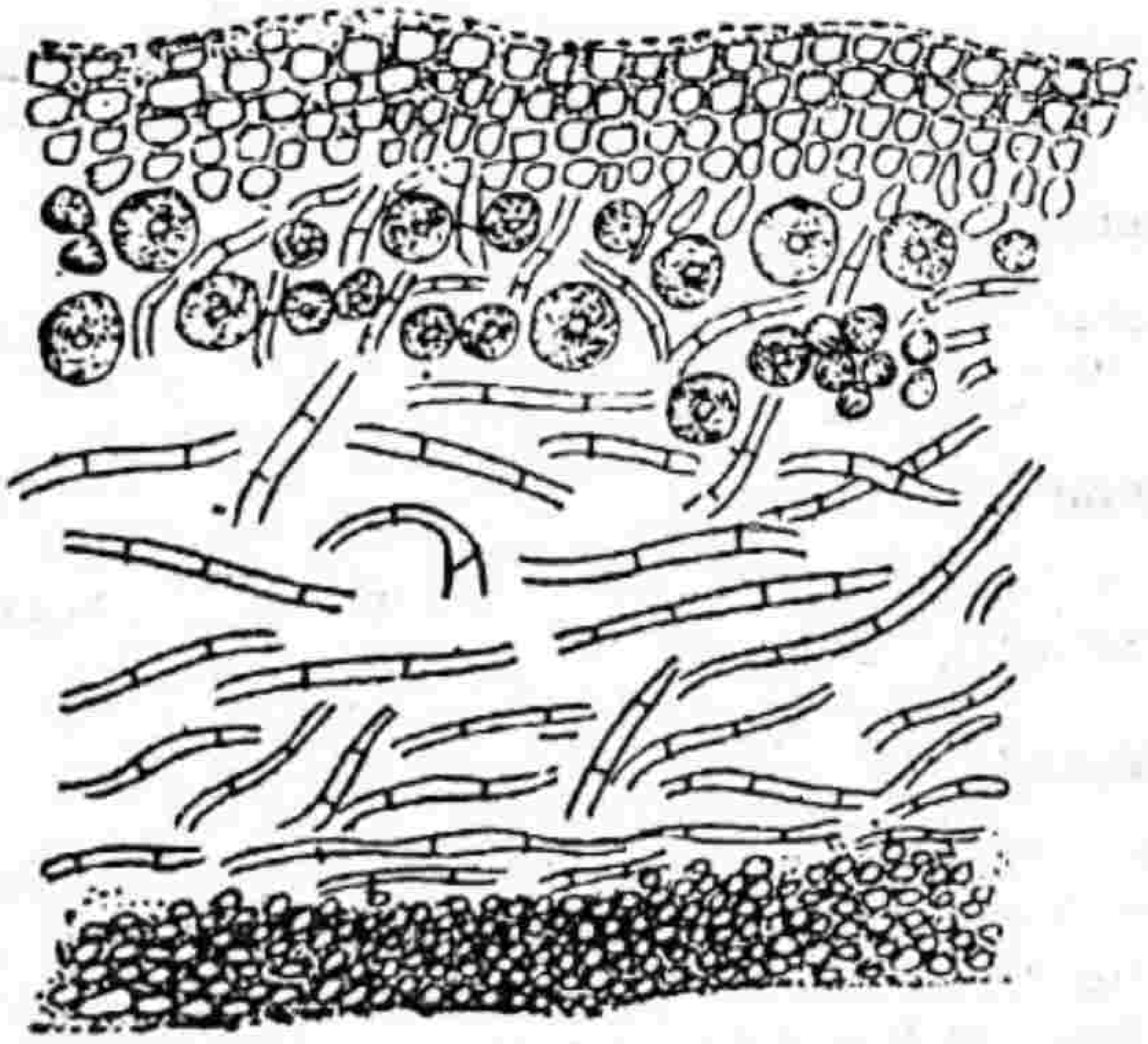


Fig. 5.29: V.S. of Thallus.

REPRODUCTION

The lichens reproduce by vegetative, asexual and sexual types of reproduction

Vegetative Reproduction

The lichens reproduce vegetatively by the following methods.

i.Fragmentation

It is the most effective way of reproduction is in foliose and fruticose lichens. The thalli break into smaller units called fragments due to mechanical stress or due to death of older portions of the thalli. This results in separation of the growing areas, each of which is capable of growing into a new lichen thallus.

ii.Isidia

These are small smooth or papilla-like outgrowths present on the upper surface of the thallus. Each isidium consists of algal cells and fungal hyphae surrounded by a cortical layer. These act as reproductive propagules which are carried away to some suitable environment after detachment and grow into new thalli. These are found in *Parmelia, Pseudovernia, Bryoria and Usnea.* These also help in increasing photosynthetic area of the thallus.

iii.Soredia

These are microscopic, bud-like outgrowths of algal cells surrounded by fungal hyphae that are not covered by the cortex. The developing soredium ruptures cortex and to become exposed. Therefore, these appear as special pustule-like areas called sorelia on the thallus. The soredia are dispersed by wind, animals or splashing rain-drops and each soredium develops into a new thallus. The soredia are found in *Parmelia, Bryoria and Cladonia* spp.

iv.Blastidia

In some lichens, e. g., *Physcia opuntiella* yeast-like segmented propagules known as blastidia are formed which develop into new thalli upon detachment.

Asexual Reproduction

The component organisms also reproduce independently by formation of asexual spores. These include conidia, pycnidia and by oidia formation.

Sexual Reproduction

As the lichen thalli have a dual nature, therefore, the sexual reproduction of both the partners is discussed hereunder separately.

Reproduction of Mycobionts

Since the fungal partner of a lichen may belong to Ascomycotina, Basidiomycotina or Deuteromycotina, therefore they reproduce by formation of their characteristics spores, the ascospores, basidiospores, and spermatia. These spores are released from the lichen thallus and germinate to form mycelium that combine with free algal cells under favourable conditions to synthesize the lichen thallus.

Sexual Reproduction in Ascolichens

The ascolichens reproduce by ascospores produced in asci which are arranged in an ascocarp, a cup-shaped apothecium or a flask-shaped perithecium as describe in Physcia as type specimen.

Importance of Lichens

Economically the lichens play beneficial roles mostly. A few of these are as followings:

i.Role in Establishing Ecosystems

Lichens are pioneers of succession that establishes a terrestrial ecosystem, as these initiate soil formation. The lichens growing on rocks secrete organic acids and help in chemical weathering of the rocks.

ii.Role in Nitrogen Fixation

The lichens in which the algal partner are blue-green algae are important components of certain ecosystems where they play an important role in nitrogen fixation and provide bulk of fixed nitrogen.

iii.Role as Pollution Indicator

The lichens are important and reliable pollution indicators. These are used to measure atmospheric pollution in industrialized areas due to their physiological sensitivity. The algal partners of the lichens are sensitive to SO_2, therefore can be used to monitor air quality of a particular area.

iv.Cause of Fire in Forests

Some species of Usnea are responsible for fires in forests as these catch fire due to inflammable nature of their thalli.

v.Source of Food

Many lichen species contain a carbohydrate allied starch, the lichenin which make them valuable source of food especially in antarctic regions. For example, Cladonia rangifera, commonly termed as reindeer moss, and other tundra lichens serve as food for reindeers, musk ox and other wild animals of tundra range.

vi.Commercial Products

A number of commercial products such as dyes used to dyeing woollen and silk fabrics, litmus used as acid-base indicator, and essential oils for perfume manufacturing are obtained from lichens. Some species of lichens are used in manufacture of soap. The chemicals obtained from some lichens are used in tanning leather. Similarly some species are used in preparation of alcohols and brewing beers.

vii.Medicinal Use

Many chemicals are found in the lichen thalli which have medicinal value and are helpful in curing various diseases. For example: usnic acid produced by a number of lichen species is used in preparation of antibacterial creams; Peltigera canina (dog lichen) is used for bites of a mad dog (hydrophobia); some lichen spp produce protolichesterinic acid which is used in preparation of anti-cancer drugs; and Lobaria pulmonaria (lungwort) and Cetaria islandica is used to control tuberculosis and other pulmonary diseases.

vii.Toxins

Certain lichen species such as Letharia vulpina contain poisonous substance, vulpinic acid used to get rid of wolves mixed with powdered glass.

PHYSCIA

Kingdom:	Fungi
Division:	Ascomycota
Class:	Lecanoromycetes
Order:	Teloschistales
Family:	Physciaceae
Genus:	*Physcia*

Physcia is a foliose ascolichen, in which the fungal partner belongs to ascomycetes. It is found growing on rocks, old wood, trees mostly. The species grow on ground rarely.

PLANT BODY

The plant body is a foliose (leaf-like) thallus attached to the substratum through rhizines. The fungal partner belongs to Ascomycotina and the algal partner is usually Trebouxia, a green alga.

Internally the thallus is differentiated into four layers. The uppermost region consists of more or less vertical hyphae that round off in some species to form pseudoparenchyma. The tissue may or may not contain intercellular spaces. The spaces, if present are filled with gelatinous material. This region is called upper cortex. Beneath the upper cortex algal partner is present intermixed with loosely interwoven fungal hyphae. This layer is called algal layer. The algal layer is followed by medulla composed of very loosely interwoven hyphae. Below this layer is the lower cortex formed by hyphae that lie parallel to the lower face of the thallus. From underside of the lower cortex rhizines arise that fix the thallus to the substratum.

Reproduction

Physcia reproduces both by vegetative and sexual reproduction.

Vegetative Reproduction

The various methods of vegetative reproduction in Physcia are:

i. Fragmentation:

It is the usual method of vegetative reproduction in Physica. The thallus is broken into smaller parts, the fragments either due to death of older cells or accidental injury. Each fragment develops into a new thallus if it contains both algal and fungal components.

ii. Soredia:

The soredia develop as white pustules on the upper surface of thallus. Each soredium contains algal cells enveloped in fungal hyphae. It develops into new thallus upon detachment.

Pycnidia and Pycnidiospores

Flask-shaped asexual reproductive bodies, the pycnidia are present embedded in the Physcia thallus. Small, rounded, unicellular spores, the pycniospores are produced in these pycnidia, but these act as spermatia.

Sexual Reproduction

Physcia reproduces sexually by formation of septate sexual spores, the ascospores, produced in asci which develop in a cup-shaped fruiting body, the apothecium.

Reproduction of Fungal Component

The sex organs in Physcia are ascogonium and spermatium (pycnium).

Ascogonium

The female sex organ is called as ascogonium. The ascogonium develops from a hypha deep in the algal layer. It is filamentous with a basal coiled portion forming the oogonium and an elongated receptive portion, the trichogyne. The trichogyne may project out of thallus in certain species. Many ascogonia are produced at one point but only one matures and becomes fertile.

Spermatium

The male sperms are produced in flask-shaped reproductive body, the spermogonium. Ity opens to the outer surface of the thallus through a pore called ostiole. The inner surface of the spermogonium is line with fertile hyphae. Male gametes, the spermatia are produced at the tips of these hyphae.

Fertilization

The spermatia are carried to the receptive hypha of the ascogonium and the wall of contact between these two dissolves. The male nucleus migrates into the oogonium. The male and female nuclei arrange themselves in pairs at the periphery of the oogonium wall.

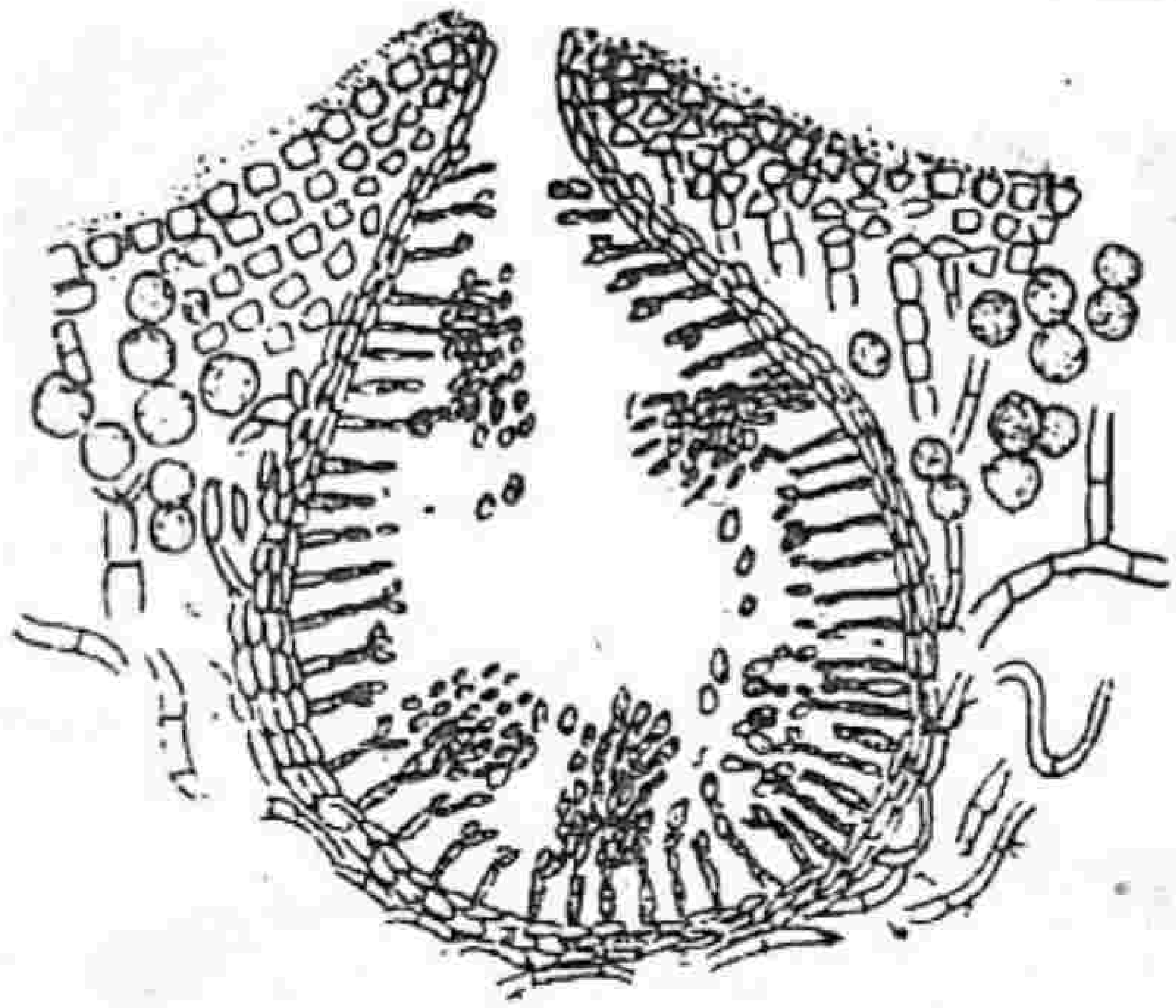


Fig. 5.30: V.S. of Spermatangium

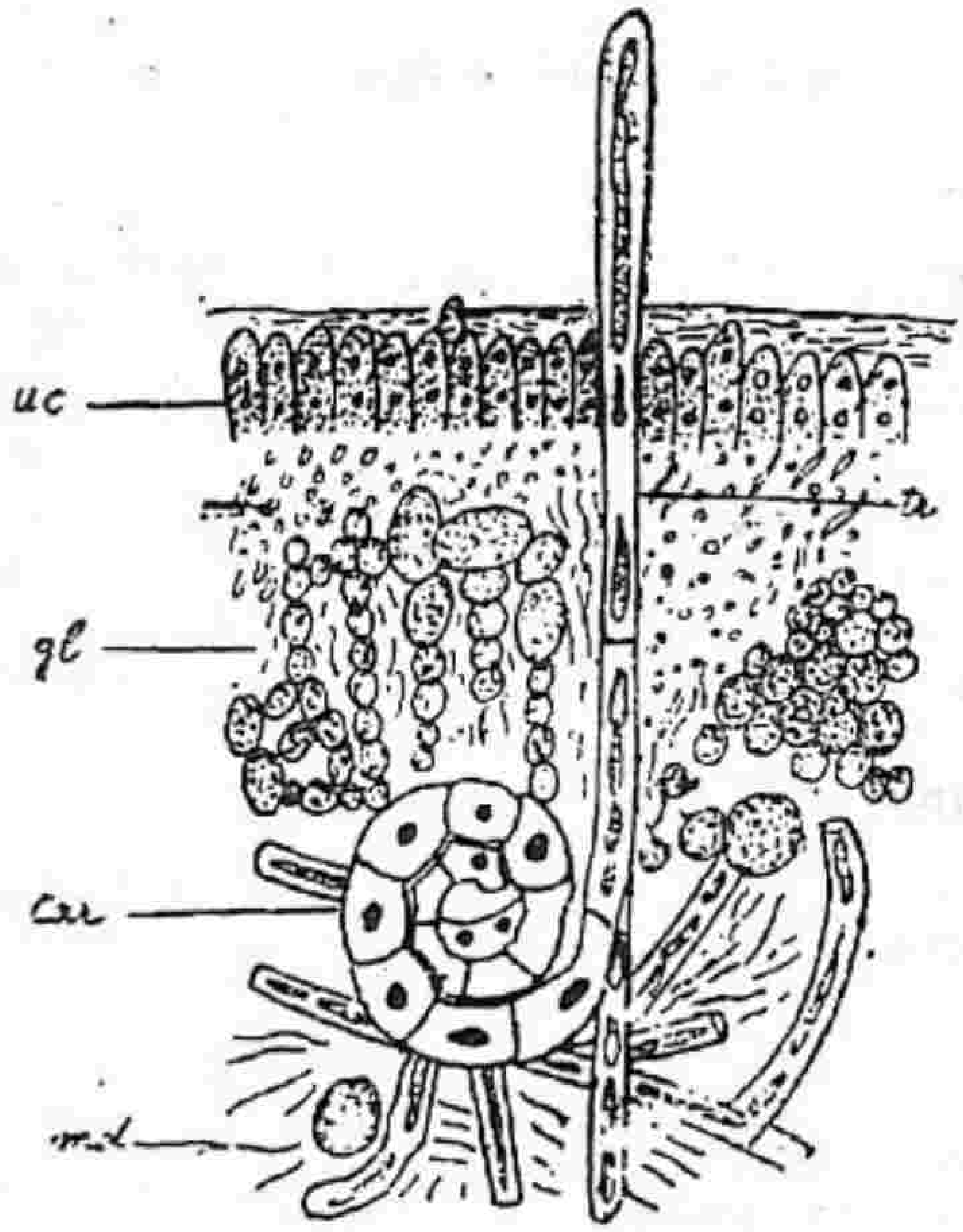


Fig. 5.31: V.S. of Thallus showing Carpogonium.

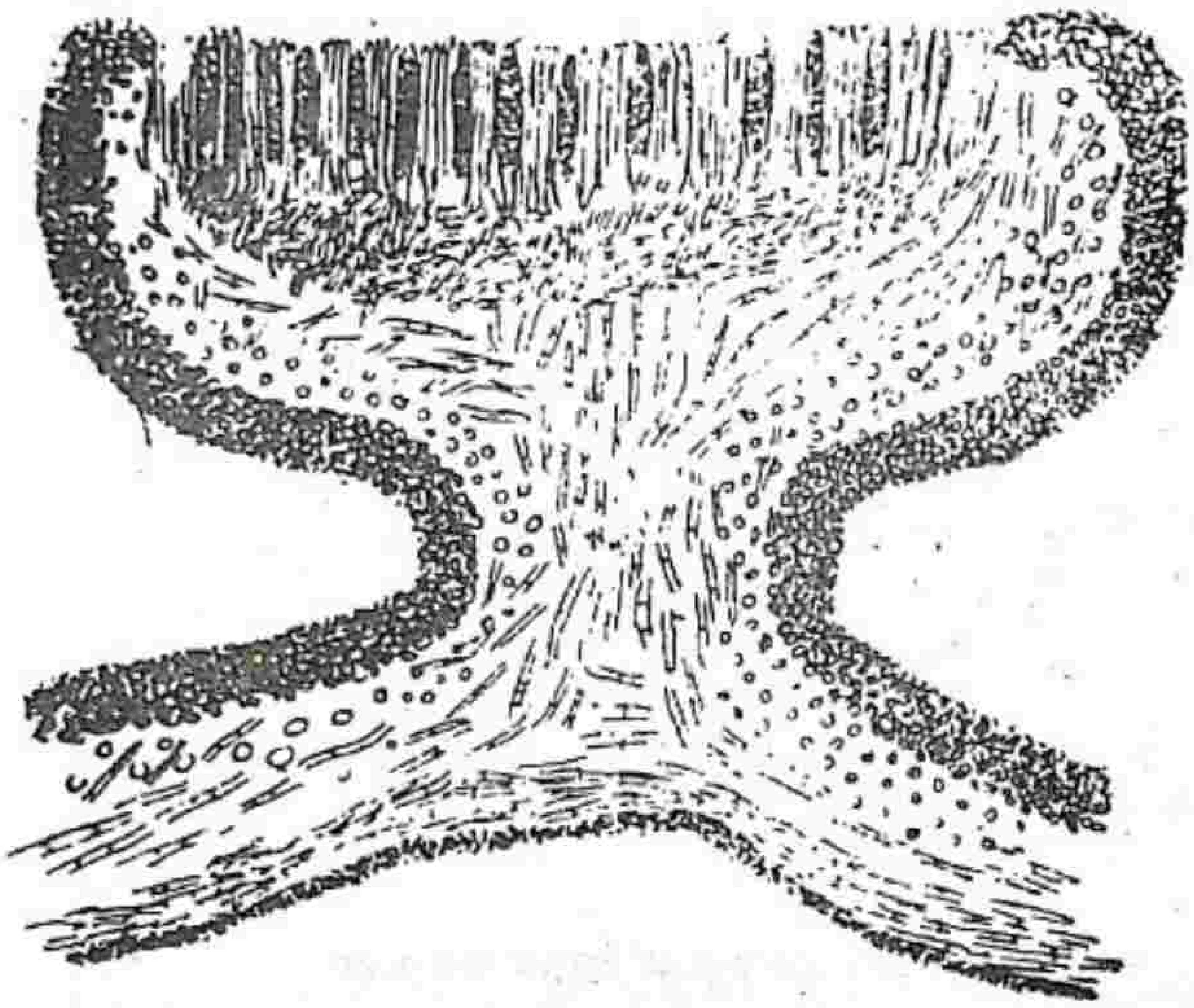


Fig. 5.32: V.S. of Apothecium.

Ascus Formation

The stimulus of fertilization results in the development of ascogenous hyphae from the wall of the oogonium. As these hyphae are developing, the diploid zygote nucleus divides and migrate into the ascogenous hyphae which become septate. The asci develop from the terminal cell of ascogenous hyphae. The karyogamy takes place in ascus mother cell. The fusion nucleus divides to form eight ascospores by free cell formation. The asci elongate vertically and arrange themselves in a layer, the hymenium. Sterile vertically hyphae called paraphyses develop among the asci. In the meantime hyphae present below the spermogonium develop and form the wall of the fruiting body.

Reproduction of Algal Partner

The algal cells associated with Physcia reproduce either by ordinary cell division or by formation of aplanospores.

Synthesis of Thallus

The ascospores upon release from the asci germinate to produce hyphae. These hyphae grow in all directions and when come in contact with a suitable alga, these produce additional branches that enfold the alga, and in this way new lichen thallus develops.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are lichens.
2. What is the morphology of lichen.
3. What is a heteromerous lichens
4. What is a soredia.
5. Describe fragmentation in lichens.
6. What is mycobiont.
7. Give two importance of lichens.
8. Is lichen is pollution indicator.
9. Draw internal structure of lichen thallus.
10. Give taxonomic position of lichens.

B. Long Questions

1. Describe life cycle of lichen.
2. Describe internal structure of lichen thallus.
3. Describe sexual reproduction in lichens.
4. What are economic importance of lichens.

SECTION VII

THE BRYOPHYTA

Chapter 6

960–24000

BRYOPHYTES

Small, nonvascular plants e.g moss, liverwort and hornworts.

The term Bryoph[illegible]a (Gr. bryon=moss + phyton=plant) is applied to a group of plants in which the plant body is simple flat thallus. still in the process of developing resembling to some of thallophyta in vegetative structure, but showing an advance in the method of reproduction. The sex organs are multicellular and each sex organ is protected by an outer wall of sterile cells surrounding sex cells.

They exhibit distinct heteromorphic alternation of generations. The principal (dominant) phase is gametophyte. It is conspicuous and nutritionally independent. The sporophyte is simple and comprises of foot, seta and capsule. It never becomes independent, but remains attached to the gametophyte throughout its life.

GENERAL ACCOUNT OF BRYOPHYTES

Habitat

About 960 genera and 24,000 species of bryophytes exist in the universe. They range from few mm to 30 cm or more in size. With the exception of few aquatic forms they are truly land plants.

They are found in humid and shady places. The bryophytes are abundant in moist mountain forests .of tropical and sub-tropical region. Species like *Riccia*, *Marchantia*, *Anthoceros* and *Funaria* are common in the plains.

Water is required at the time of fertilization, therefore they are commonly called amphibians of the plant kingdom.

Plant Body

The gametophyte is haploid (n) and an independent plant at maturity. In many cases the gametophyte is a thallus, i. e., plant body is without differentiation into root, stem and leaf, for example in *Marchantia* and *Anthoceros*. In others it is externally differentiated into stem and leaves, however there are no roots. The absorbing organs are rhizoids.

The sporophyte is diploid (2n) and dependent upon gametophyte for its nutrition and remains attached to the gametophyte. It consists of foot, embedded in the gametophyte and absorbs nutrition from it; seta which raises the sporophyte above the level of gametophyte, and conducts food absorbed by the foot; and capsule, the spore producing structure. The sporophyte of the bryophytes is generally called a sporogonium.

Reproduction

The bryophytes reproduce by vegetative, sexual and asexual modes of reproduction. The gametophyte reproduces sexually by formation of gametes whereas the sporophyte reproduces by formation of spores, therefore the mode of reproduction is asexual.

Vegetative Propagation

In some species asexual reproduction takes place by the vegetative methods of fragmentation and gemmae. However, asexual spores like endospores or akinetes produced in algae are absent.

Sexual Reproduction (gametes)

The sexual reproduction is oogamous type. The gametes are produced in multicellular sex organs. The male gametes are small and motile, while the female gametes are large and non-motile.

The sex organs are antheridia and archegonia. These are multicellular and each sex organ is protected by an outer wall of sterile cells surrounding sex cells. Both kind of sex organs may develop on the same plant (monoeious or homothallic) or on different plants (dioecious or heterothallic).

Each antheridium is usually club-shaped. It contains androcytes or antherozoid mother cells surrounded by a single layer of sterile jacket cells. Each androcyte metamorphoses into a motile biflagellate antherozoid or male sperms. The archegonia are usually flask-shaped. Each archegonium consists of a basal swollen portion, the venter and an elongated part, the neck. An axial row of cells surrounded by jacket of sterile cells is present in the neck and venter. It consists of few neck canal cells, a ventral canal cell and an egg or oosphere.

Fertilization

Water is essential for fertilization. The jacket of mature antheridium ruptures liberating the sperms. The motile flagellated sperms swim in the film of water and reach the neck of an archegonium. In the meantime axial row of neck canal cells disorganize and the tip of the archegonium ruptures opens. The antherozoids enter the neck and swim down to the egg. One of these sperms fertilizes the egg to produce zygote.

The zygote is retained within the venter and develops into an embryo without delay. The wall of venter enlarges alongwith the developing embryo to form a protective, multicellular envelope, the calyptra.

The zygote undergoes repeated divisions to form an undifferentiated, multicellular structure, the embryo. The first division of the zygote is transverse and the apex of the embryo develops from the outer cells. The cells of embryo undergo differentiation to produce a sporogonium representing the sporophyte.

Asexual Reproduction (spores) => sporophyte

A mature sporogonium consists of a basal swollen foot, a stalk or seta, and a spore-producing structure, the capsule. The capsule comprises of sporogenous cells surrounded by a layers of sterile cells. These cells undergo divisions repeatedly and last generation of cells is called spore mother cells which undergo meiosis to produce tetrads of haploid spores. The spores are non-motile, cutinized, wind-disseminated and alike, therefore the bryophytes are homosporous. In most cases, e. g., in *Riccia* and *Marchantia*, sterile cells called elators are also produced alongwith spores.

✓Germination of Spores ⇒ on (sporophyte) ⇒ produce gametophyte :-

Each spore upon falling on a suitable place germinates to a gametophyte plant directly or into a filamentous or thalloid green protonema which give rise to the thallus (gameotphyte).

Alternation of Generations

The life cycle of bryophytes exhibit alternation of generations. There is an independent, haploid, gamete-producing generation, the gameotphyte. It bears sex organs, the antheridia and archegonia, in which male and female gametes are produced. Fertilization requires water and the resultant zygote develops into an embryo that matures into diploid, dependent spore-producing structure, the sporogonium (sporophyte). The sporogonium remains attached to the gametophyte and draws nutrition from it. It is differentiated into foot, seta and capsule. The capsule contain spore-producing cells that undergo meiosis to produce tetrad of meiospores. The spores upon germination produce an independent gametophyte plant.

✓AFFINITIES OF BRYOPHYTES ✓ final ✓

✓ There are no known fossil bryophytes, therefore origin of bryophytes can be traced only through comparative morphology and ontogeny of present day living plants. There is an almost universal belief that bryophytes arose from green algae, probably from Chlorophyta. However, some people hold that bryophytes have descended from pteridophytes.

bryophyte origin

✓ 1.Origin from Algae

The origin of bryophytes from algae is supported by the following facts:

(i) There is close resemblance between chlorophylls and xanthophylls of algae to that of bryophytes.

(ii) The presence of motile sperms in bryophytes supports algal ancestry.

(iii) The development of a green, filamentous, alga-like protonema in the life cycle of ~~some~~ bryophytes support their origin from algae. (thread like chain of cells.)

It is generally believed that the following steps occurred during the course of evolution from algae to bryophytes:

✓ i.Evolution of Sexual Thallus of a Bryophyte

due to evolution of sexual thallus of bryophyte.

An oogamous alga migrated from water to land and this was followed by evolution of a sexual thallus of a bryophyte with sexual organs characteristics of bryophytes. However, there is possibility that the migratory ancestor may be isogamous and changed to oogamy after migration to land. This is supported by the fact that an evolution from isogamy to oogamy have appeared in many independent lines of algae.

✓ ii.Appearance of Alternation of Generations

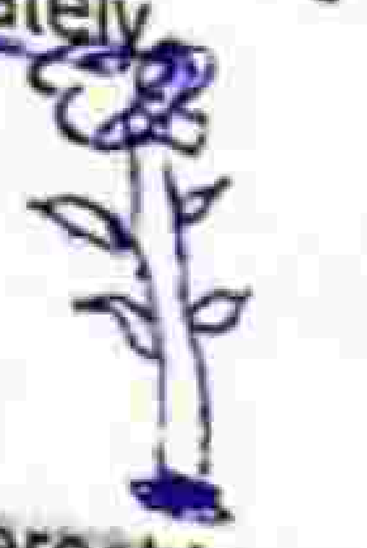
Simultaneous with migration there was an appearance of alternation of generations. At one time it was believed that an alternation of generations appeared after the first land plant had arisen from an algal ancestor that had migrated to land. But, later it was found that in many distantly related taxa of green algae, for example, *Chaetophorales, Cladophorales and Ulvales,* the alternation of generations has arisen independently. Thus, it is possible that alternation of generations found in bryophytes did

(♀ + ♂) (spore)

not appear after the sexual thallus of algal ancestor had evolved to sexual thallus of a bryophyte. Therefore, the possible origin of two generations is discussed separately.

iii. Origin of the Gametophyte

⇒ ①



There are two views regarding the evolution of bryophyte gametophyte:

a. According to one school of thought the primitive gametophyte was an erect leafy plant. However, such an evolution is not proved any known green alga.

② b. The second school of thought was of the view that primitive gametophyte was a simple thallose structure with no external or internal differentiation. This type of gametophyte may have evolved from parenchymatous green alga *Fritschiella*.

iv. Origin of the Sporophyte

There are two theories regarding the origin of sporophyte.

Modification or Homologous Theory

According to this theory the sporophyte is direct modification of the gametophyte. The proponents of this theory consider sporophyte a neutral generation meant for production of spores. Both the gametophyte and sporophyte generations were isomorphic, free-living and complex in structure. But in time the sporophyte became permanently attached to the gametophyte, partially dependent upon it, and this resulted in reduction of complexity of the sporophyte.

The evidence supporting this theory includes:

④
a. Presence of isomorphic alternation of generations in certain algae,
b. Photosynthesis in the sporophytes of bryophytes,
c. The presence of tracheids in the gametophytes of pteridophytes, and
d. Apogamy and apospory.

(without any) water conducting cell in xylem.

development of a plant without fusion of gamete.

development of gametophyte without spores.

INTERCALATION OR ANTITHETIC THEORY

(insertion)

According to this theory the sporophyte originated as an entirely new structure intercalated between two successive gametophytic generations. The sporophyte evolved after the sexual plant has evolved archegonium. During the course of evolution, the zygote became retained permanently on the gametophyte, as in *Coleochaete*. The meiosis is delayed and zygote divided mitotically to give rise to diploid tissue homologous with sporophyte of bryophytes. Later the cells underwent meiosis and produced haploid spores, which developed into haploid phase. Further evolution came about as a result of additional sterilization of sporogenous tissue resulting in differentiation of foot, seta and capsule. This progressive sterilization is noticed in abnormal sporophytes of Porella where internal portions of foot and seta are sporogenous.

zygote
⇓
[illegible]
⇓
2n sporophyt
⇓
(n)

foot, seta + capsule

Recent evidence from the ultra-structural studies has provided support for antithetic theory and suggests the origin of sporophyte in the green algae. In Coleocheate, the retention of zygote stimulate the neighboring cells to divide and form a sterile, protective covering around it. These cells also provide nutrition to the zygote. Thus, Coleocheate or Coleocheate-like alga may have resulted in the simple type of sporophyte found in liverworts such as *Riccia, Ricciocarpus*, etc. Also, it has been demonstrated that cytokinesis in *Coleocheate* involves a phragmoplast such as present in all land plants; and ultrastructure of sperm resembles those of land plants. ✓

2.ORIGIN FROM PTERIDOPHYTES

The proponents of this belief were of the view that bryophytes have evolved from pteriodphytes through progressive simplification or reduction. The origin of bryophytes from the pteridophytes is traced from the following facts:

i. There is close similarity between the sex organs of two groups.

ii. The sporogonium of *Anthoceros* resembles with terminal sporogonium of fossil pteridophytes such as Sporogonites and Horneophyton.

iii. Similarity in pigments, structure of cell wall, food reserves, reproductive methods and life cycle, further strengthen these ties.

Scott (1911) was the first to advocate origin of bryophytes from pteriodphytes on the basis of presence of chlorophyll and plastids in the sporogonium of liverworts, mosses and Anthoceros. The other features were presence of stomata in the sporogonium Anthoceros and apophysis region in capsule of mosses. He suggested that these characters of ancestral pteriodphyte plant were retained. The immediate descendant was believed to be Anthoceros.

Kayshap considered that liverworts have evolved from Equisetales along three independent lines Marchantiales, Jungermanniales and Anthocerotales.

Haskell (1949) considered that bryophytes have evolved from algae through Psilophytes by simplification. The resemblance between Anthoceros sporogonium and terminal sporogonium of Horneophyton, presence of stomata similar to those in vascular plants, and presence of apophysis in the capsule of mosses, were considered chief characteristics.

The hypothesis did not claim wide recognition because of absence of vascular system in bryophytes. It is known that water ferns after adapting aquatic mode of life have retained their vascular system.

ECONOMIC AND ECOLOGICAL IMPORTANCE OF BRYOPHYTES

Although about 24,000 species of bryophytes exist, but none of these is of direct use to man except the peat moss (Sphagnum), hair cap moss (Polytrichum) and some liverworts (Marchantia). However, they influence man through their role as rock builders, in soil conservation, etc.

Some important direct and indirect economic and ecological importance of bryophytes is as under:

i.Bryophytes and Peat Formation

Peat is a brown or dark coloured spongy matter produced as a result of partial decay of dead organic matter in the bog, and due to compression and carbonization under pressure by the overlapping deposits and water. Sphagnum and other mosses are chief components of the peat. The peat is rich in carbon, therefore used as fuel in generating power, in making illuminating gas, in preparation of ethyl alcohol, etc. It is also used in horticulture. It is added to the clayey and sandy soils to improve their texture. Since peat can retain moisture it is used to as packing material for shipment of live plants, vegetables, perishable fruits, etc.

ii.Role in Soil Conservation

Since bryophytes grow in dense stands forming a mat, they prevent soil erosion. The intertwined moss stems and underground rhizoids bind the soil particles firmly. They can hold large amount of water and reduce the run off.

iii.Role in Soil Development

The mosses alongwith lichens play an important role in soil development on the surface of a bare rock. The lichens are pioneers and they are replaced by mosses during succession. The mosses can retain moisture and form humus to build the substratum. Most herbs germinate among these mosses.

iv.Role as Rock Builders

Certain bryophytes such as *Bryum, Hypnum, Fissidens*, etc growing in association with other aquatic plants like Chara play a remarkable role as rock builders. These plants grow in waters rich in calcium bicarbonate. They decompose calcium bicarbonate releasing carbon dioxide. The insoluble calcium carbonate precipitates, hardens and form lime rocks.

v.Role as Pollution Indicators

It has been demonstrated that both alive and air dried mosses particularly Sphagnum can absorb metals. Because of this property they are used as atmospheric and aquatic pollution indicators and in mineralogical surveys.

v.Medicinal Use of Bryophytes

Marchantia polymorpha,Anthoceros, Riccia and Polytrichum spp are reported to have medicinal properties. They are used as antitumor, to cure pulmonary tuberculosis and afflictions of the liver. Similarly *Polytrichum commune* is used to dissolve stones of kidney and gall bladder. A distillate of peat tar called sphagnol is used in treatment of skin disease. The Sphagnum is used for making absorbent bandages in treatment of boils and discharging wounds.

vi.Bryophytes as Source of Antibiotics

In recent years it has been reported that bryophytes are antibiotically active. *Conocephalum conicum, Dumortiara hirsuta* and *Sphagnum strictum* have been tested for their antibiotic activities. The first two have been reported to inhibit the growth of *Candida albicans*. The *Sphagnum* spp inhibit the growth of *Staphyloccous aureus*. Uptil now about 52 species of bryophytes belonging to 40 genera have been tested for their antibiotic activities and found to inhibit growth of 18 bacterial genera such as *Sarcina lutea, Bacillus subtilis*, Escherichia coli, Salmonella typhi, Vibrio cholerae, etc; and 3 fungal genera *Aspergillus niger*, *Curvularia lunata* and *Hemithosporium oryzae*.

vii.Bryophytes as Experimental Tools

The liverworts and mosses are used as experimental tools in various disciplines of botany such as genetics, experimental morphology and physiology. Polyploidy had been studied in bryophytes.

viii.Bryophytes as Source of Food

Bryophytes are not directly used as food, however some species of bryophytes are used in manufacture of different kinds of food. *Brym* and *Polytrichum* capsules are used in chick food. The *Sphagnum* is used as a famine food in China.

CLASSIFICATION OF BRYOPHYTES

OUTLINE OF CLASSIFICATION BY ROTHMALER AND OTHERS

Division:Bryophyta

Class 1:Hepaticopsida

The members of the class are commonly termed liverworts. They include plants in which the gametophytes are dorsiventrally differentiated, and are either thallose, i. e., not differentiated into root, stem and leaves; or foliose, i. e., differentiated into stem and leaves. The sex organs either develop at the tips of erect branches or on the dorsal surface of the thallus. The sporophyte is differentiated into foot and capsule. In some species seta is also present. The sporogenous cells develop from endothecium. The capsule wall is several layered.

The class includes three orders: Sphaerocarpales, Marchantiales (Marchantia, Riccia), Jungermanniales and (Pellia, Porella). These order include 9 families, 225 genera and 8,500 species.

Class 2:Anthocerotopsida

The class includes bryophytes commonly called hornworts. It includes plants in which the gametophyte is thalloid mostly and dorsiventrally differentiated. The sex organs are embedded on dorsal surface of the thallus. The sporogonium is elongated and consists of foot, a meristematic region and capsule. The sporogenous cells develop from amphithecium. The capsule wall is many layered. The outer layers contain stomata and chloroplasts. There is a central sterile column of tissue in the center of the capsule called columella.

The class includes a single order: Anthocerotales, 3 families, 6 genera and 301 species.

Class 3:Bryopsida

The members of the class are commonly called mosses. The gametophyte consists of prostrate filament from which erect branches arise. The erect branches bear spirally arranged leaves. The sex organs develop at the tips of special erect branches, the gametophores. The sporophyte is differentiated into foot, seta and capsule. The capsule is well developed. The outermost capsule wall layer contains stomata. The sporogenous cells develop from outer layer of endothecium. A central sterile column, the columella is present in the center of the capsule.

The class includes 3 sub-classes: Sphagnidae (Sphagnum), Andreaeidae (Andreaea), and Bryidae·(Funaria, Polytrichum)28 families and 14,504 species.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are bryophytes.
2. What are liverworts.
3. Define alternations of generations in bryophytes.
4. What is the role of bryophytes in soil conversation.
5. What is peat moss.
6. What is role of bryophytes in pollution indicator.
7. Enlist the antibiotics obtained from bryophytes.
8. What is gammae.
9. What are mosses.
10. Give some characteristics of bryophytes.

B. Long Questions

1. What are bryophytes. Give its economic importance.
2. Describe origin of bryophytes.
3. Give classification of bryophytes.
4. Give general account of bryophytes.

HEPATOPHYTA * ✓.

The division Hepatophyta (Gr. hepar=liver) or liverworts, contains over 300 genera and 6,000-10,000 species. The division includes most simple extant land plants which vary in size from minute leafy forms to large, lobed types. Several genera are aquatic and the remainder are restricted to moist habitats. The important genera are *Ricciocarpus, Riccia, Pellia, Marchantia, Sphaerocarpos.*

CLASS:HEPATOPSIDA (HEPATICEAE)

The division includes a single class Hepatopsida. It comprises of about 35 genera and 420 species. The well known members of the class are *Marchantia, Preissi, Dumortiera, Cyathodium, Riccia*, etc.

General Characteristics

i. The members of the class grow in moist habitats on damp soil or rocks. A few are aquatic. Some are capable of growing in dry conditions.

ii. The dominant generation is thallose gametophyte. The thallus is green, flat, dorsiventral, lobed and dichotomously branched. The dorsal surface is characterized by presence of many polygonal areas with an air pore in the center. From the lower surface smooth or tuberculate rhizoids arise. The ventral surface also contains scales.

iii. The thallus is internally differentiated into a dorsal assimilatory region and a ventral storage region. In certain species, e. g., in Marchantia air chambers containing photosynthetic filaments are present in dorsal region.

iv. Most members of the class reproduce vegetatively by fragmentation (Riccia, Marchantia), production of adventitious branches (Riccia), gemmae formation (Marchantia) and tuber formation (Riccia).

iv. The sex organs are of two kinds, the antheridia and archegonia. They may be borne on the same thallus (homothallic) or on different thalli (heterothallic). The sex organs may be borne on thallus (Riccia) or on specialized erect branches receptacles, the gametophores (Marchantia).

v. Following fertilization, the zygote develops into spore-bearing structure, the sporogonium that represent the sporophyte. The sporogonium remains covered and protected by enlarged venter called calyptra.

vi. The sporogonium is differentiated into foot and capsule. The archesporium produces spores and elators. In Marchantia seta is present between foot and capsule. As the spores mature, the seta elongates and carry capsule through the calyptra. The spores are dispersed through wind.

vii. The class include seven orders.

RICCIA

Systematic Position

Division:	Bryophyta
Class:	Hepaticopsida
Order:	Marchantiales
Family:	*Ricciaceae*
Genus:	*Riccia*

Riccia belongs to the family Ricciaceae of the order Marchan-tiales. Majority of the species of this genus are terrestrial but some species are aquatic as these are found growing actually in the water. The following seven species have been commonly reported from the North Western Himalayas and the Punjab plains: *Riccia robusta*; *R. melanospora*; *R. cruciata*; *R. sanguinea*, *R. himalayansis*; *R.fluitans*nd *R.pathankotensis*. *Riccia robusta*; *R. sanguinea* and *R. pathankotensis* are very common in the Punjab plains (found growing on the moist soil in places like river beds, banks of rivers and canals, and along the streams.)

VEGETATIVE STRUCTURE

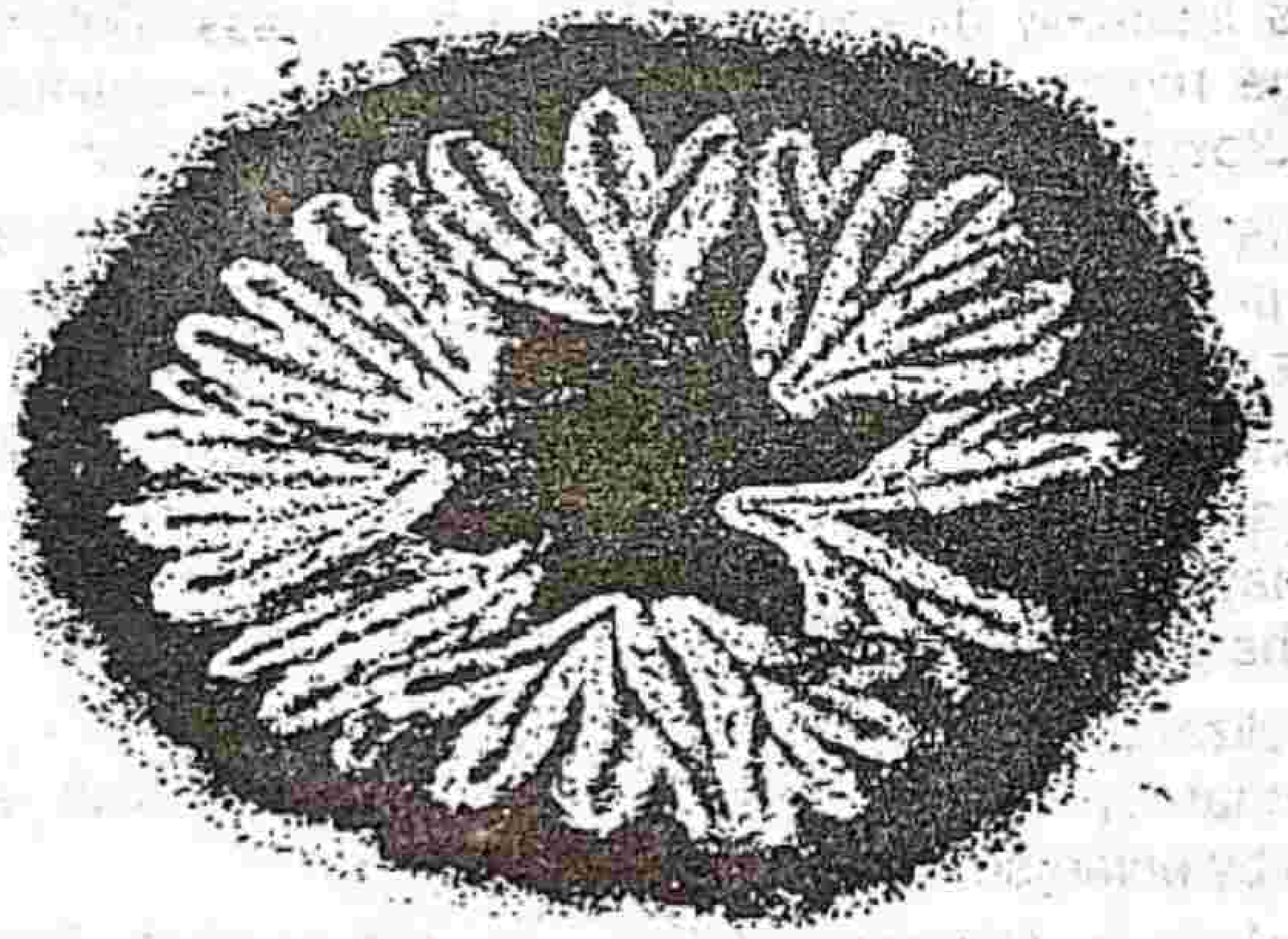


Fig. 6.1: Riccia

Riccia is a thallose liverwort in which the vegetative plant, which is a gametophyte, generally forms rosettes due to the crowded growth of the thallus lobes, this crowded growth of the various lobes is due to the repeateddichotomies of the thallus. The thallus lobes arc flat growing horizontally on the soil and each lobe has a small notchat theapexwhere the growing pointissituated. The lobes are thicker in the middle and gradually become thinner towards the margins.A deep cleft or furrow is commonly present inthe middle of each lobe on the dorsal side; the sex organs are found embedded in this furrow. The lobes in *Riccia fluitans*, which is an aquatic species, are narrow and ribbon-like having repeated dichotomous branches which do not form any

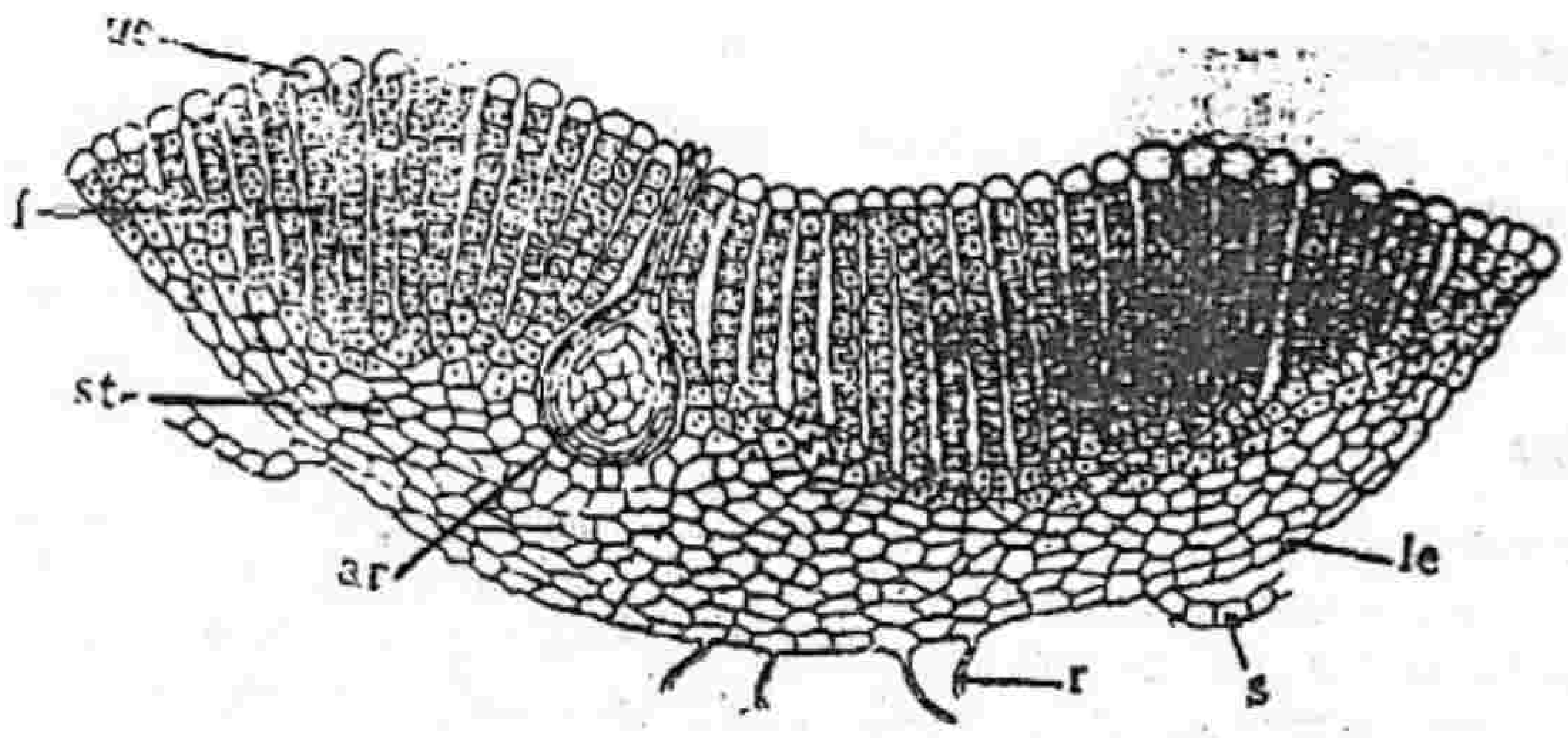


Fig 6.2:. Riccia »p. Vertical section of a thallus (ue, upper epidermis; r, rbizoid; s, scale; le, lower lepidemiis; St, storage region; af, assimilatory regioD; ar, archegonium).

rosetts. Numerous unicellular rhizoids are found attached to the ventral side of the thallus, these rhizoids are generally crowded in the middle part of the thallus and are of two types i.e., smooth and tuberculate as in Marchantia. The ventral side also bears scales which are formed of a single layer of cells and are arranged in two rows in the older parts of the thallus while in the younger parts these scales are in one row and in the apical region are crowded below the notch for the protection of the growing point.

INTERNAL STRUCTURE OF THE THALLUS

The thallus of Riccia has a simple structure and is formed of parenchymatous cells which are bounded on both sides by the upper and lower epidermis. Internally the thallus is differentiated into two regions, upper assimilatory region and the lower storage region. The storage region is formed of compactly arranged parenchymatous cells which are either colourless or contain only few chloroplasts, but these cells are rich in starch grains.Some of the cells of the lower epidermis grow out and elongate forming the rhizoids, while certain cells divide and produce the single layered scales. In the majority of species the assimilatory region is formed of vertical rows of cells which are about six to eight cells in height and are separated by large air spaces, the cells of these filaments are rich in chloroplasts as these form the main photosynthetic tissue. The cells of the upper epidermis are also loosely placed having spaces in between them which function as pores through which the underlying air spaces communicate out for the exchange of gases. In some species the assimilatory region is spongy being formed of irregularly placed air spaces which are separated from each other by single layered partitions whose cells are 'rich in chloroplasts.

REPRODUCTION

Ricciaplants, like other liverworts, multiply vegetatively by the decay or death of the older parts which results in the separation of younger branches, each of which grows into an independent plant. In certain species {R. fluitans) small adventitious lateral branches may be produced from the ventral side of the thallus, these adventitious branches on detachment give rise to new plants. Formation of vegetative reproductive gemma-like multicellular bodies at the apices of rhizoids have also been reported in certain species.

SEXUAL REPRODUCTION

Riccia plants may be monoecious or dioecious depending upon the species. Both the male (antheridia) and female (archegonia) reproductive organs are produced in acropetalous order on the dorsal side of the thallus in the median furrow. In the monoecious species the antheridia are generally produced earlier than the archegonia.

ANTHERIDIA

Antheridia are found in a linear row on the dorsal side of the thallus embedded in the median furrow.Each antheridium is a globular structure having a very short insignificant stalk.The wall of the antheridium consists of a single layer of cells and encloses a mass of androcytes or antherozoid mothercells. At maturity the contents of each androcyte are transformed into a typical coiled biflagellate antherozoid. When the antherozoids are produced the original walls of the androcytes become gelatinous thus producing a mucilaginous mass in which the antherozoids float freely. The antherozoids are released in the surrounding water by the bursting of the antheridial wall and then these swim freely in the water.

DEVELOPMENT OF THE ANTHERIDIUM

Each antheridium develops near the apex from a superficial cell which divides transversely into a lower basal cell and an outer cell.The basal cell divides further producing the basal part of the antheridial stalk which remains embedded in the thallus tissue.The outer cell divides transversely producing a row of four cells.The two lower cells of this row by further transverse and vertical divisions produce a short stalk of the antheridium. In the upper two cells of the row two vertical divisions take place at right angle to each other producing a group of eight cells or octants.Periclinal divisions then take place in these octants producing outer jacket initials and inner androgonial initials. The jacket initials by.further anticlinal divisions only produce the single layered wall of the antheridium; while the androgonial initials by further transverse and vertical divisions produce a mass of androgonial cells which are enclosed by the single layered wall. The last division in each androgonial cell is diagonal thus producing two androcytes

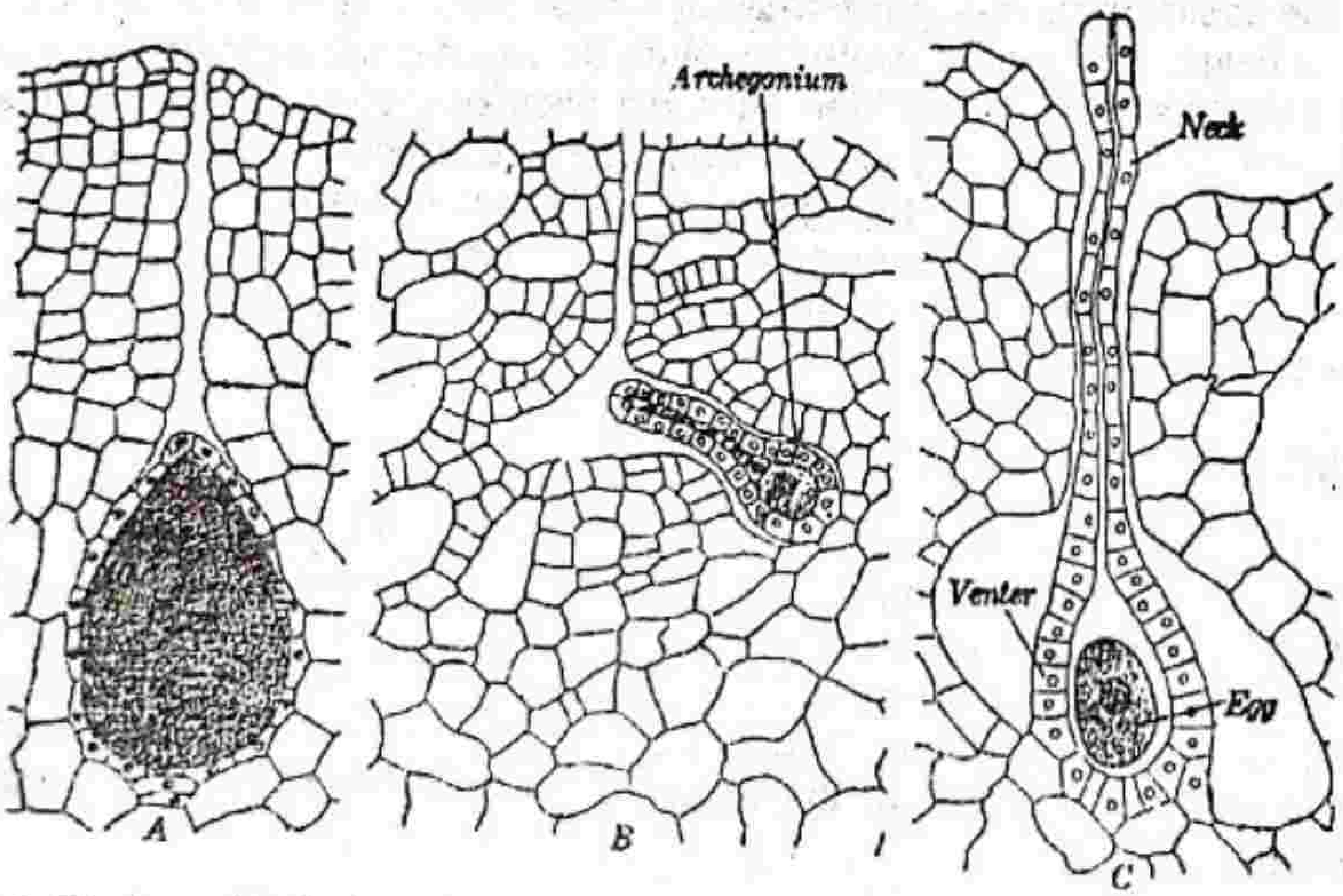


Fig. 6.3: Riccia sp. Vertical section of the thallus showing: A, a mature antheridium; B, a young archegonium; C, a mature archegonia .

(antherozoidmother cells). The contentsofeach.androcyte are transformed into an antherozoid.As the development of the antheridia is going on the surrounding vegetative tissue grows up and the antheridia become embedded in the dorsal furrow. The thallus continues its growth at the apex while the development of the antheridia is going on, therefore, the mature antheridia are lying some distance back from the apex.

ARCHEGONIA

The archegonia, like the antheridia, are also embedded in the mid-dorsal furrow of the thallus and are arranged in acropetalous order i.e., the younger archegonia lie towards the growing point while the older ones are towards the hinder region. Each archegonium is a flask-shaped structure having a multicellular stalk. The basal swollen portion of the archegonium is known as the venter and the upper elongated portion as the neck. The wall of the neck consists of a single layer of cells which are arranged in six vertical rows. The canal of the neck contains a row of four neck canal cells and is closed at the tip by four lid cells. The wall of the venter is also formed of a single layer of cells which are arranged in several vertical rows.The venter contains a lower larger cell, the egg or oosphere, and a smaller upper cell known as the ventral canal cell. The necks of the mature archegonia protrude out above the general surface of the thallus. When the archegonia are mature the ventral canal cell and the neck canal cells disorganise forming mucilaginous mass which swells by absorbing water and comes out the neck by pushing apart the lid cells thus forming an opening for the entry of antherozoids.

DEVELOPMENT OF THE ARCHEGONIUM

Each archegonium develops from a superficial cell situated on the dorsal side about three or four cells away from the growing point. This archegonial initial divides by a transverse division into an upper primary cell and a lower primary stalk cell. The primary stalk cell by further transverse and longitudinal divisions produces a short multicellular stalk.In the primary archegonial cell three excentric vertical divisions take place resulting in the production of three peripheral cells around an axial cell.A vertical division takes place in each peripheral cell resulting in the production of six jacket initials.The axial cell cuts of a small cover cell at the tip.A transverse division takes place in all the cells resulting in the production of a lower and an upper group of cells. The upper group of peripheral cells divides by transverse divisions only producing the single layered wall of the neck in which the cells remain arranged in six vertical rows.The lower group of peripheral cells by further anticlinal divisions produces a single layered wall of. the venter in which the cells are not arranged in six vertical rows. In the meantime the axial cell by a transverse division has divided into an upper neck canal initial and a lower central cell. The neck canal initials produce a row of four neck canal cells.The central cell divides producing an egg or oosphere towards the base and a small ventral canal cell towards the upper side.

FERTILIZATION

Fertilization takes place in the presence of water the antherozoids liberated in the surrounding water swim towards the archegonia, being attracted chemotactically by the mucilage coming out of the archegonia. Several antherozoids may enter a single archegonium but only one of them fuses with the egg for fertilization. The male and female nuclei fuse together producing a single diploid nucleus. The fertilized oosphere secretes a wall and becomes the oospore which develops into the sporogonium.

SPOROGONIUM OR SPOROPHYTE

The mature sporogonium in *Riccia* is of very simple structure. It is globular or rounded in shape and is enclosed in the enlarged venter of the archegonium. This sporogonium is not differentiated into foot, seta and capsule as in other liverworts. The wall of the mature capsule consists of a single layer of cells surrounding a mass of spore mother cells. The mature sporogonia are embedded in the tissue of the thallus and are visible to the naked eye as small black dots on the thallus. The nucleus of each spore mother cell undergoes meiosis (reduction division) producing four haploid nuclei, and each spore mother cell then divides into four uninucleate parts, each of which is transformed into a single haploid spore. The four spores produced from each spore mother cell remain held together in tetrads for a long time.

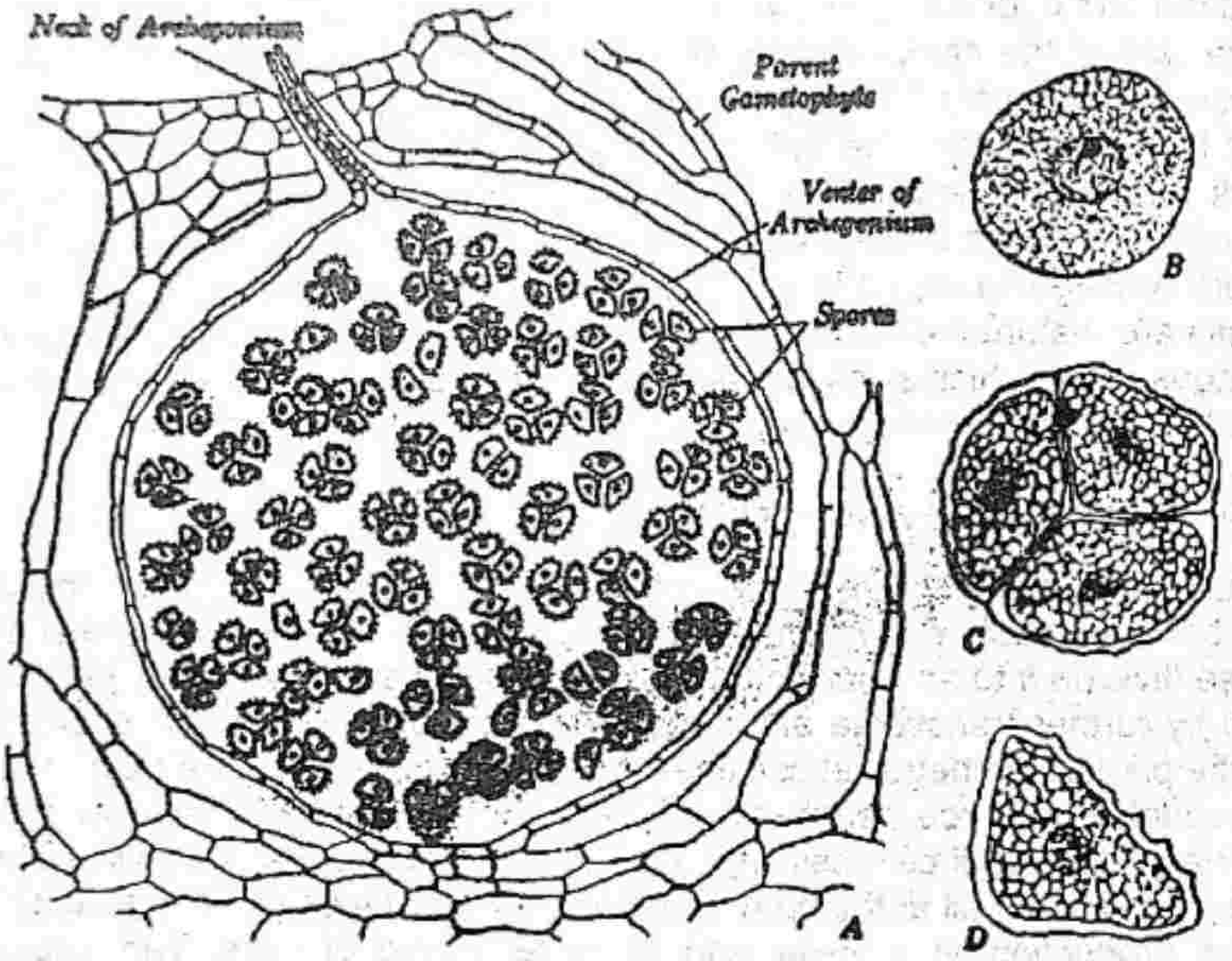


Fig. 6.4.RIccia sp.A, a mature sporogonium; B, a spore mother cell; C. a spore teterad; D, a single spore.

The wall of each mature spore is very unevenly thickened and it consists of three layers; the outer exosporium which is thin, hard and cutinised; the middle mesosporium which is very thick and soft; and the inner endosporium which is membranous. All the spor(mother cells in a sporogonium are generally transformed into spores there are no sterile cells or elaters. In certain species few sport mother cells do not produce spores but disorganise producing a mucilaginous fluid.The original wall of the sporogonium disorganises producing a mucilaginous fluid before the maturation of spores. The mature spores are actually enclosed by the outer layer of the enlarged venter which is often mistaken as the sporogonium wall (Fig. 3-4). The spores are released by the bursting of the wall of the enlarged venter which is comparable to the calyptra of other liverworts. The release of spores is delayed for a long time till the decay of the vegetative tissue, which may take even a year or so after the maturation of spores.

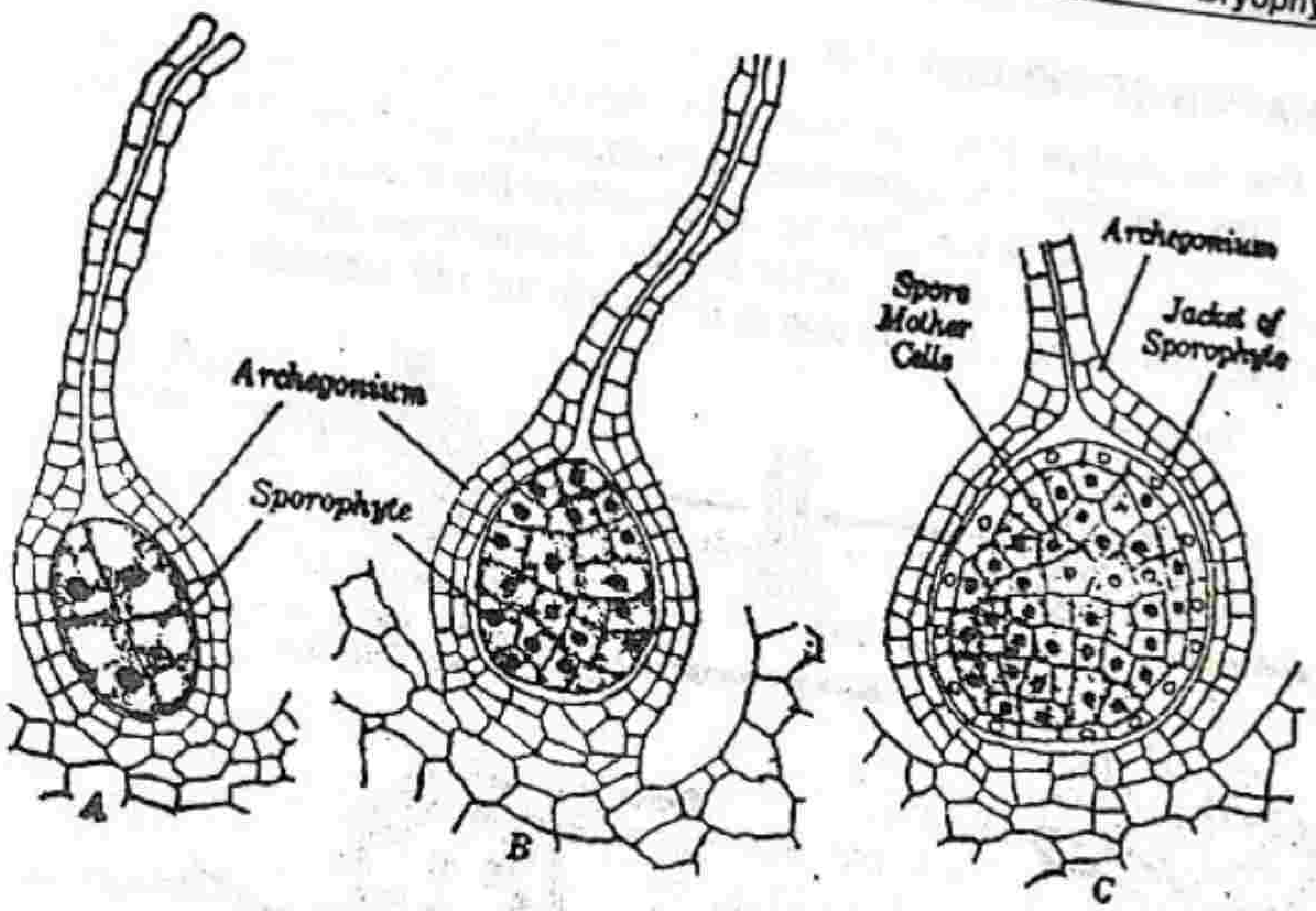


Fig. 3—5.*Ricciasp.*A—C.

Fig. 6.5: Development of Sporogonium.

DEVELOPMENT OF THE SPOROGONIUM

The oospore increases very much in size filling the whole cavity of the venter. This enlarged oospore then divides by two vertical and onetransverse division, all at right angle to each other, producing a group of eight cells or octants. These octants divide further producing a group of about 20-30 cells. Then the periclinal divisions take place in. these cells resulting in the production of an outer layer of jacket initials or amphithecium and an inner mass of archesporial initials or endothecium. The cells of the amphithecium by further anticlinal divisions give rise to a single layered wall of the sporogonium; while the cells of the endothecium by repeated divisions produce a mass of archesporial cells.

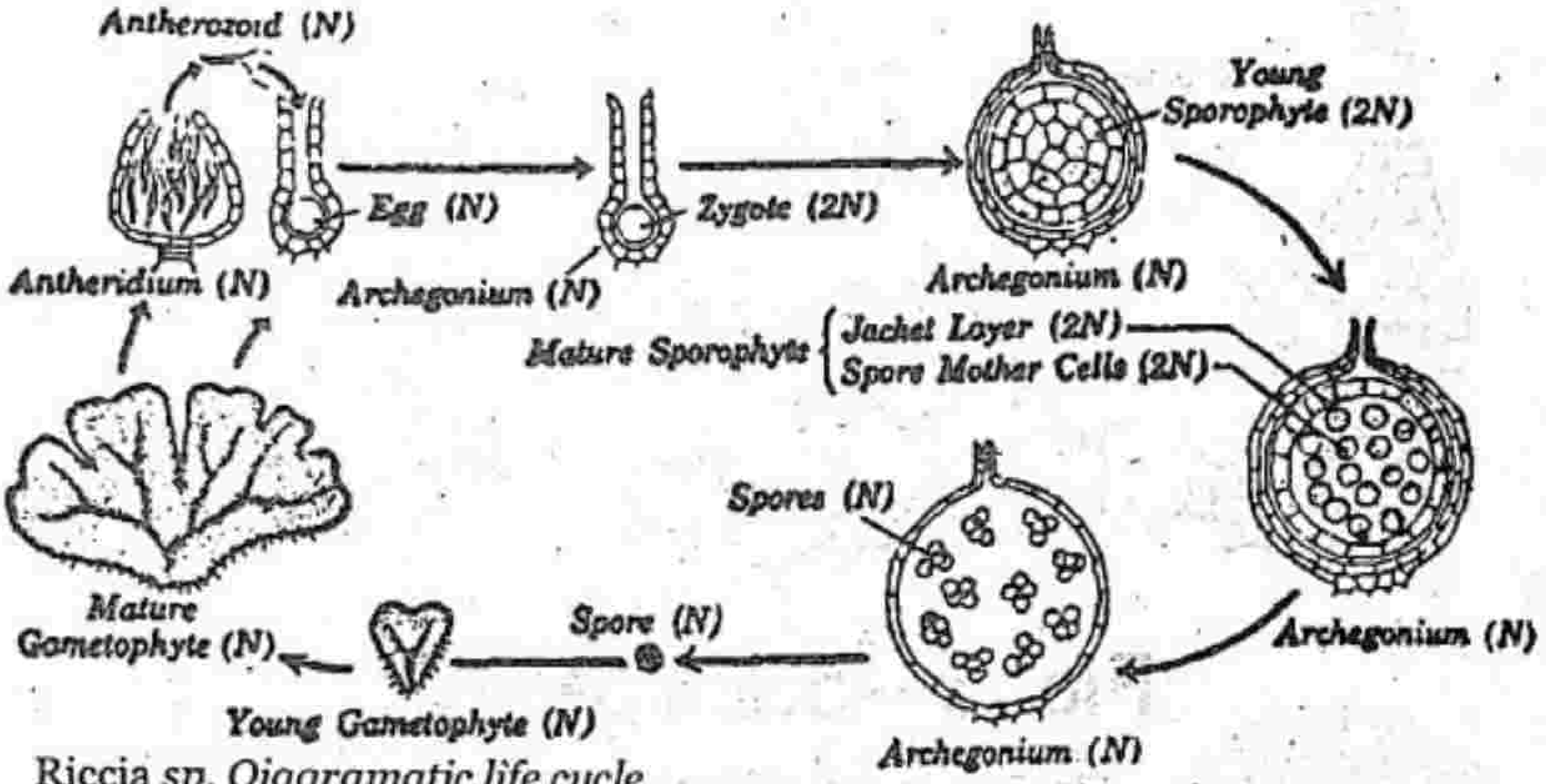
When the development of the sporogonium is initiated periclinal divisions take place in all the wall cells of the venter making the venter wall double layered. The venter goes on increasing in size along with the developing sporogonium, and in this way the mature sporogonium remains enclosed in the double layered wall of venter.Thecells ofinner layer oftheventer wall thesporogonialwall alongwithsomesporemother c disorganiseproducingaviscousliquid.Each spore mother cell produces the four spore the usual method after the reduction division of its nucleus, spore mass is enclosed in the outer layer and not by the sporogonium wall which has disorganised. As all stated the mature spores are released by the bursting of this wall after a long time when the tissue of the thallus has decayed

GERMINATION OF SPORES

When a spore falls on a suitable place, it germinates by the production of a long germ tube. This germ tube is produced by the rupture of the outer hard exosporium and mesosporium, and then the endosporium forming the germ tube.The protoplasmic contents of the flow into the tip of this germ tube which becomes separated fro rest of the portion by the formation of a septum.

ALTERNATION OF GENERATION

The vegetative plant or thallus in Riccia, is a gametophyte, whose cells are haploid. This gamete producesmale(antherozoids) and female (oosphere) gamete surrounding vegetative tissue. The apical growth of the thallus continues and the mature archegonia come to lie near the hinder portion. Sometimes all the developmental stages can be traced in the single thallus due to the production of archegonia in an acropetalous succession, antheridia and archegonia respectively. The union of these gametes or fertilization results in the production of an oospore which is diploid. The oospore develops into the sporogonium or the sporophyte which represents the asexual stage as it produces the spores asexually. The spores are haploid as these have been produced after the reduction division in the spore mother cells. The spores germination give rise to the gametophyte. For the completion of the whole life cycle the gametophyte produces the sporophyte, this sporophyte produces the gametophyte again, and these two generation regularly alternate with each other.



Riccia *sp. Oiagramatic life cycle.*

Fig. 6.6: Riccia sp. Diagramatic life cycle.

PORELLA (LEAFY LIVERWORT)

Systematic Position

Division: Bryophyta
Class: Hepaticopsida
Order: Jungermenales
Sub-order: Jungermanaceae
Family: Porellaceae
Genus: *Porella*

Habit and Habitat

Porella is worldwide in distribution except in arctic and Antarctic regions. The genus is represented by 184 species. *Porella playtphylla* appears to be cosmopolitan in its distribution. The plants grow in moist shady places with preference for epiphytic habit. It grows in dense layer forming large mats. *Porella* species are remarkable in their tolerance of prolonged and periodic dying.

Vegetative Morphology-gametophyte

The plant body is composed of leafy shoots anchored to the substratum with the help of rhizoids. It is fairly and may reach 15 cm or more in length. Leaves play an important role in absorption. Nostoc colonies have been reported to be present in the crevices and curled margins of overlapping leaves.

Stem

The stem is thin, dorsiverantral and branched. The branching is bipinnate or tripinnate.

Leaves

The stem and branches bear two types of leaves, the large lateral and smaller ventral leaves. The leaves are arrangedin three rows, two of large unequally bilobed lateral leaves and one of ventral small leaves called underleaves or amphigastria.

Rhizoids

The rhizoids arise from the basal portions of amphigastria. They are few in number scattered and their chief function is to anchor plant to the substratum. They play a minor role in absorption of water.

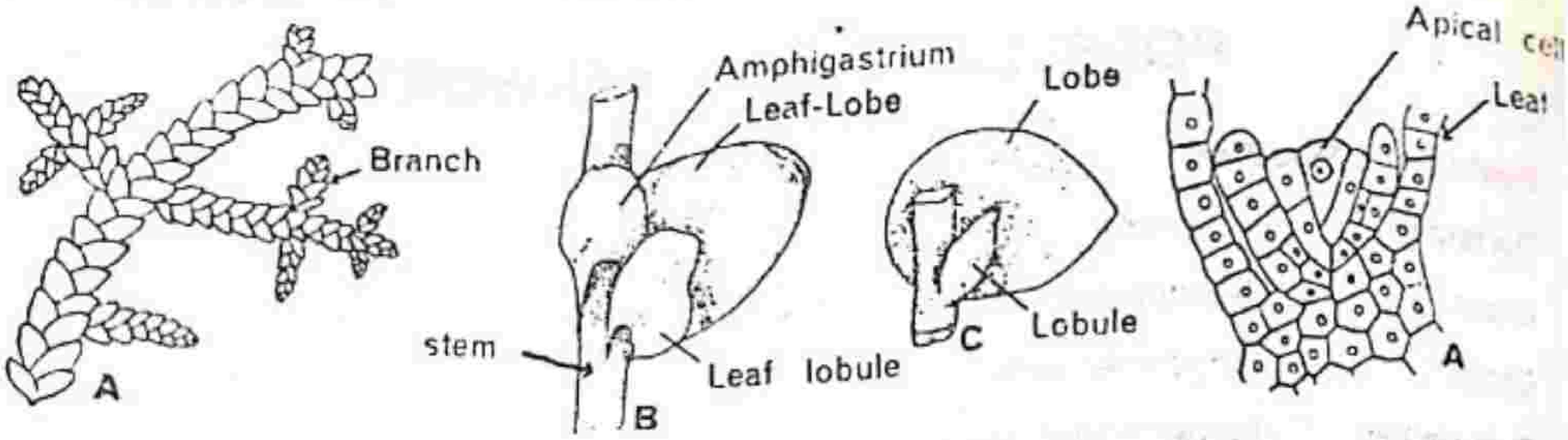


Fig. 6.7: Porella: Vegetative morphology & apical cell segmentation.

Reproduction

Porella reproduce both by means of vegetative and sexual method.

Vegetative Reproduction

The plant grows in humid conditions and propagated by means of fragmentation.

Sexual Reproduction

All species of *Porella* are strictly dioecious. The male plants are slightly narrower than female plants. The male and female plants grow intermingled in dense mat. The sex organs are antheridia and archegonia.

Structure of mature antheridium

1. Each antheridium is distinguished into long stalk and globular body.
2. Stalk consists of two rows of cells.
3. The body of antheridium has sterile jacket as an external covering.
4. Jacket enclosed a mass of spermatocyte or androcytes.
5. Each spermatocyte developed into a single biflagellate spermatozoids.

The antheridial jacket opens into a number of irregular valves due to the absorption of water. The valve get tightly curled, the individual cells get separated and force out androcytes in the water.

Archegonia

The archegonia grow at her apex of specialized less distinct short archegonial branches. A group of 15 archegonia remain surrounded by two brackets, a bracteoles and a perianth.

Structure of mature archegonium

1. The archegonium can be differentiated into a broad neck and a venter.
2. The neck consists of 5 vertical rows of cells enclosing 6-8 linearly arranged broad neck canal cells.
3. The wall of Venter consists of 5 vertical rows of cells and enclose a ventar canal cell and an egg cell.
4. Archegonia are found in a group of 15 archegonia remain surrounded by two brackets, a bracteoles and a perianth.

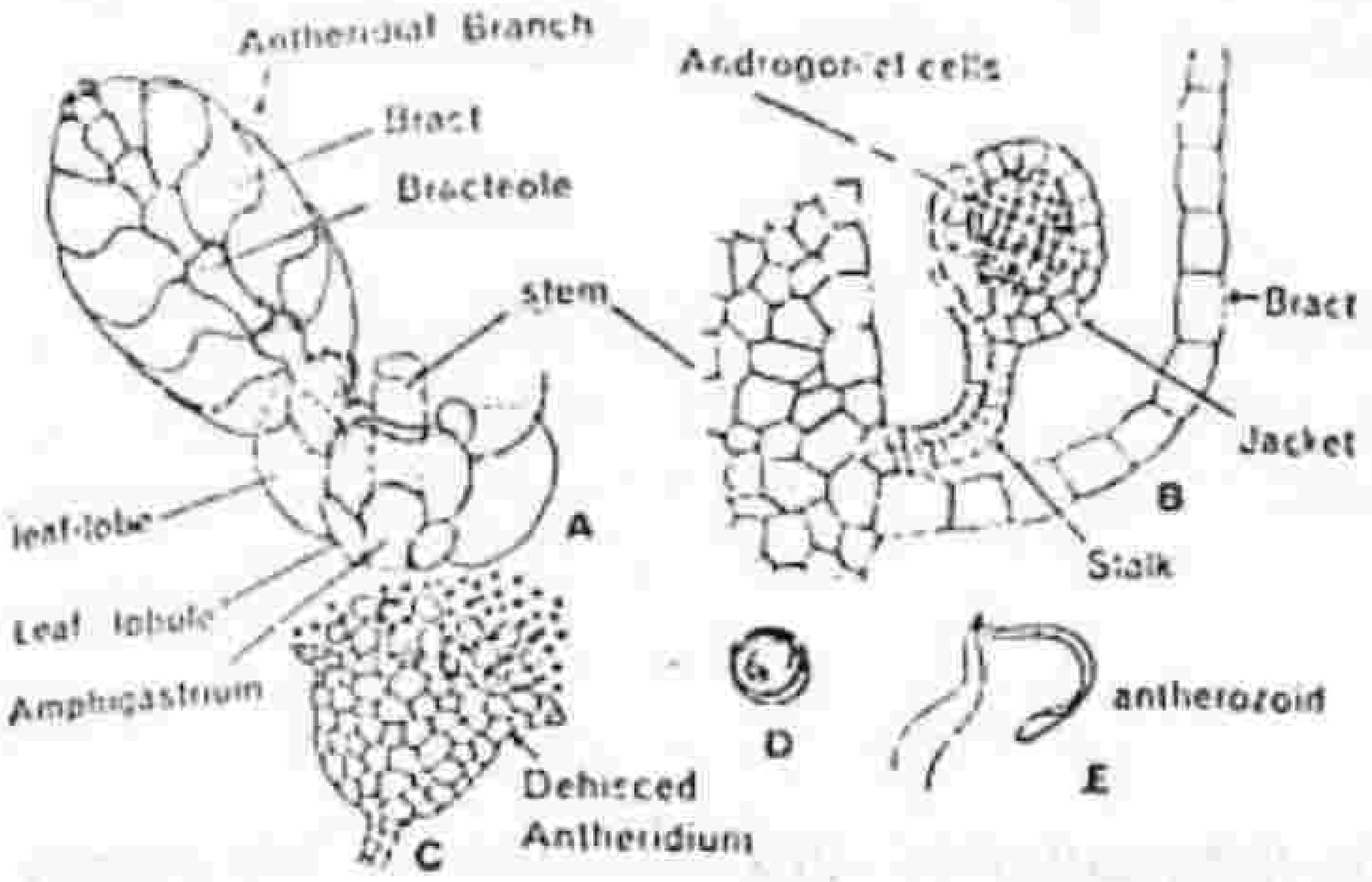


Fig. 6.8a

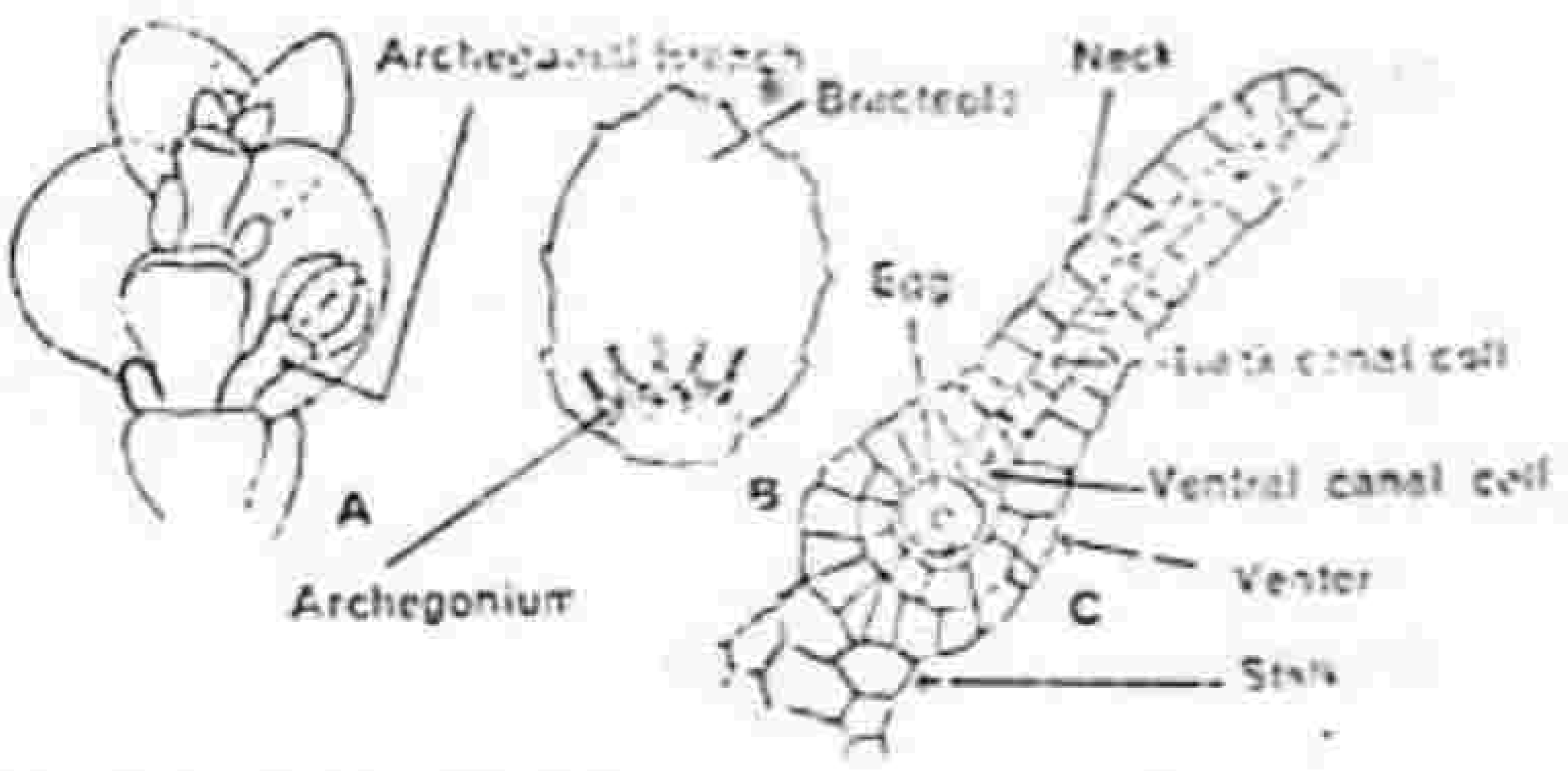


Fig. 6.8b

Fertilization and Post-Fertilization Changes

Fertilization requires water. During sufficient moist conditions, the upper jacket cells of the antheridium separate from one another at its apex and curve back to liberate the sperms. After fertilization the cluster of archegonia become surrounded by protective envelope, the calyptra. Around calyptra an inflated perianth develops by fusion of two distal bracts immediately below the archegonial cluster. It surrounds the group of archegonia. The bracts around the perianth become enlarged to form the involucre. The eggs of several archegonia in each branch may be fertilized, however only one zygote usually develops into a saprophyte. The others abort but often persist at the base of calyptra of the fertile archegonium.

SPOROPHYTE

The sporophyte in *Porella* is differentiated into a spherical capsule, a seta and a poorly developed foot.

Morphology and Development of Capsule

1. A sporophyte is differentiated into foot, seta and a capsule.
2. Foot and seta are not clearly distinguishable from each other.
3. Foot and lower part of seta are embedded in the cells of gametophyte.
4. Capsule has 2-3 cell thick sterile jacket enclosing the mass of tetrad, haploid spores and elaters.
5. The elaters are short with tapering ends. Each elater is provided with 2-3 spiral ticking band.
6. The young sporophyte remains enclosed by calyptra, a perianth and the involucer.

The zygote divides by a transverse wall into an epibasal and a hypobasal cell. The epibasal cell divides by a transverse wall into two cells to produce a 3-celled proembryo. The basal cell of proembryo does not take part in development of embryo further. The upper two cells give rise to capsule. These cells divide by successive divisions to form a mass of cells that undergoes periclinal division to give rise to outer amphithelium and inner endothelium. The amphithelium cells undergo anticlinal division first and then periclinal division to produce 2-3 layer of capsule wall. The endothelium cells act as archesporium and divide to produce sporogenous tissue. Some sporogenous cells undergo meiosis to produced four-lobed spores. The others develop into elates.

Dehiscence of Capsule

After differentiation of spores and elates, the seta cells elongate many fold to bring capsule to air. Dehiscence of the capsule takes place along four vertical rows of thin-walled cells called dehiscence lines or valves that extend half way down to the base of the capsule.

Germination of Spore

Each spore is unicellular and its wall is differentiated into two layers. The spores start germinating before these are shed from capsule (precocious). The protoplast of spore undergoes a repeated division to give rise to a globes protenema that develops rhizoids and anchor it into the soil. The protonmea establishes a tetrahedral apical cell at its edge which gives rise to news plant body.

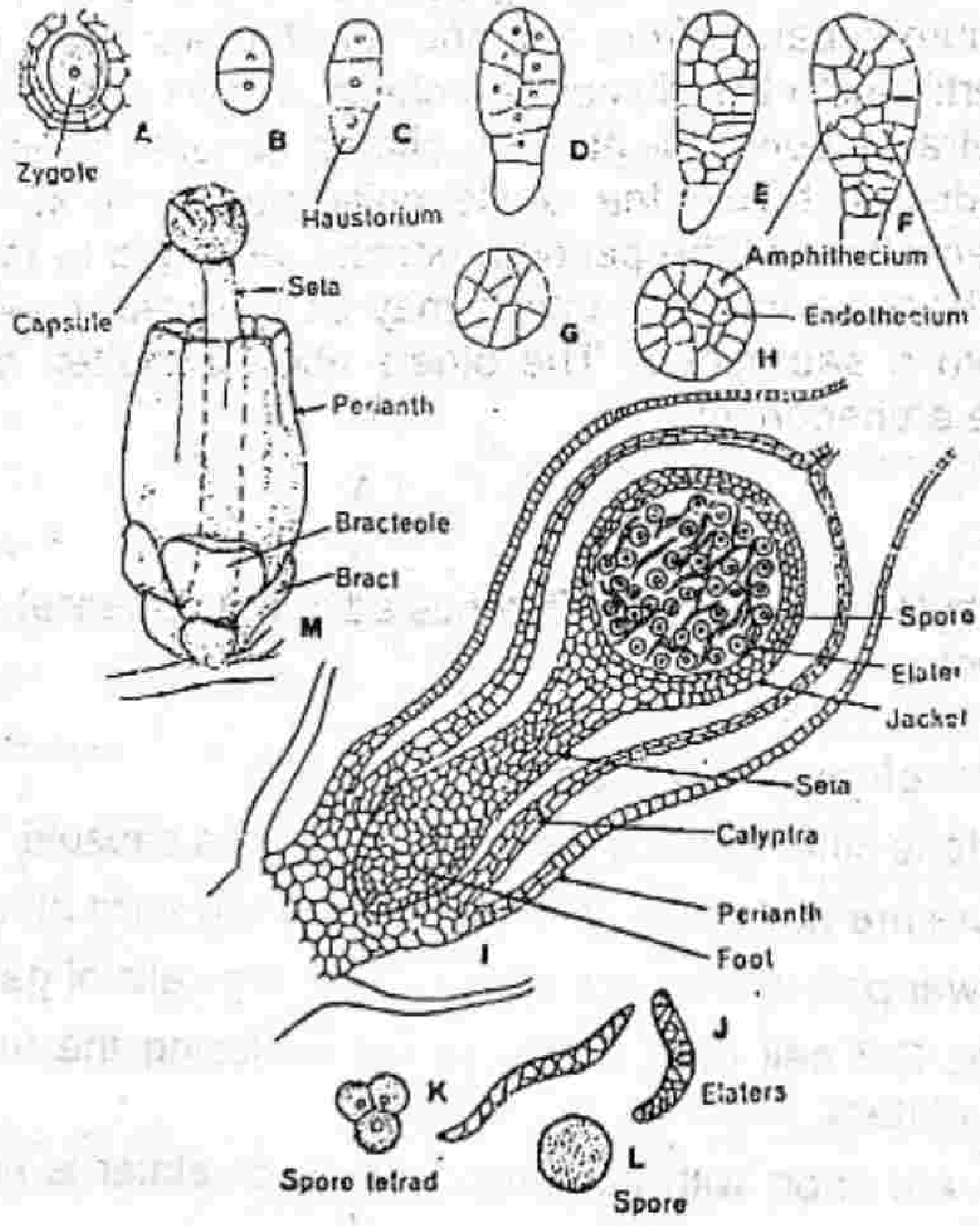


Fig. 6.9: *Porella:* Development of sporophyte

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are liverworts.
2. Define alternations of generations in Riccia.
3. Draw internal structure of thallus of Riccia .
4. Name two species of Riccia.
5. Describe structure of Porella.
6. What are leafy liverworts.
7. What is the structure of mature antheridium of Porella.
8. What is gammae.
9. What is sporophyte.
10. What is importance of capsule.

B. Long Questions

1. Describe asexual reproduction in Riccia.
2. Describe sexual reproduction in Riccia.
3. Describe sporophyte of Riccia.
4. What is alternations of generations. Describe life cycle of Riccia.
5. Describe structure and reproduction of gametophyte of Porella.
6. Describe sporophyte of Porella.
7. Describe sporophyte of Riccia and compare it with sporophyte of Porella.

✓

ANTHOCEROTOPHYTA *

The former class Anthocerotopsida was elevated to the rank of division by Stotler and Crandall-Stotler (1977).

CLASS:ANTHOCEROTOPSIDA (ANTHOCEROTAE)

The class Anthocerotopsida is a small but very clearly defined group of plants which differ from the liverworts in both its gametophyte and sporophyte. The members of this group are commonly called hornworts.

General Characteristics

i. The members of the class prefer to grow in moist, shady places and are mostly found in tropical and warm temperate region.

ii. The thallus is lobed. dorsiventral, with or without midrib. It is fixed to the substratum by simple, unicellular, smooth rhizoids.

iii. There is not much differentiation internally. There are mucilage cavities which open to the outside by slit-like openings on the lower surface of the thallus. Occasionally these cavities contain blue-green alga Nostoc.

iv. The cells of most species have a single chloroplast which contains a central pyrenoid, a feature not found in any other bryophytes and common in algae only.

v. The sex organs are sunken in the thallus. The archegonium develops from superficial cell and antheridium from hypodermal cell on the upper surface of the thallus. The antheridia lie in roofed pits.

vi. The sporophyte is long-lived and is differentiated into foot and a very long capsule. There is no seta. There is a basal meristem which adds cells to the sporophyte continuously.

vii. The capsule contains a dome-shaped cylinder, the archesporium, parallel with the elongated axis of the sporogonium. It arches over a sterile central column, the columella.

viii. The capsule dehisces basipetally from the top downwards by two valves. These are hygroscopic and curl back exposing the central column of spores and pseudoelaters.

ix. The class includes a single order Anthocerotales.

ANTHOCEROS

✓ f. P

Systematic Position

Division: Bryophyta
Class: Anthocerotopsida
Order: Antherocerotales
Family: Antherocerotaceae
Genus: *Anthoceros*

Anthoceros (Gr. anthos=flower + keras=hron) is distributed world over and grows in shady and moist areas of tropical and temperate regions of the world. It comprises of about 200 species and three common species found growing in Himalayan areas are *Anthoceros himalayensis, Anthoceros erectus* and *Anthoceros chambensis.*

Vegetative Morphology

Thallus

The plant is a gametophyte and consists of a small, grassy dark-green, prostrate thallus. The thallus is rosette-like and comprises of lobes whose margins are divided into small lobed-segments. The shape of the thallus suggests that there is repeated dichotomous branching during early phases of growth. The surface of the thallus may be smooth, velvety (A. crispulus) or contains spines or ridges (A. fusiformis). Numerous smooth-walled rhizoids are present on the ventral surface of the thallus.

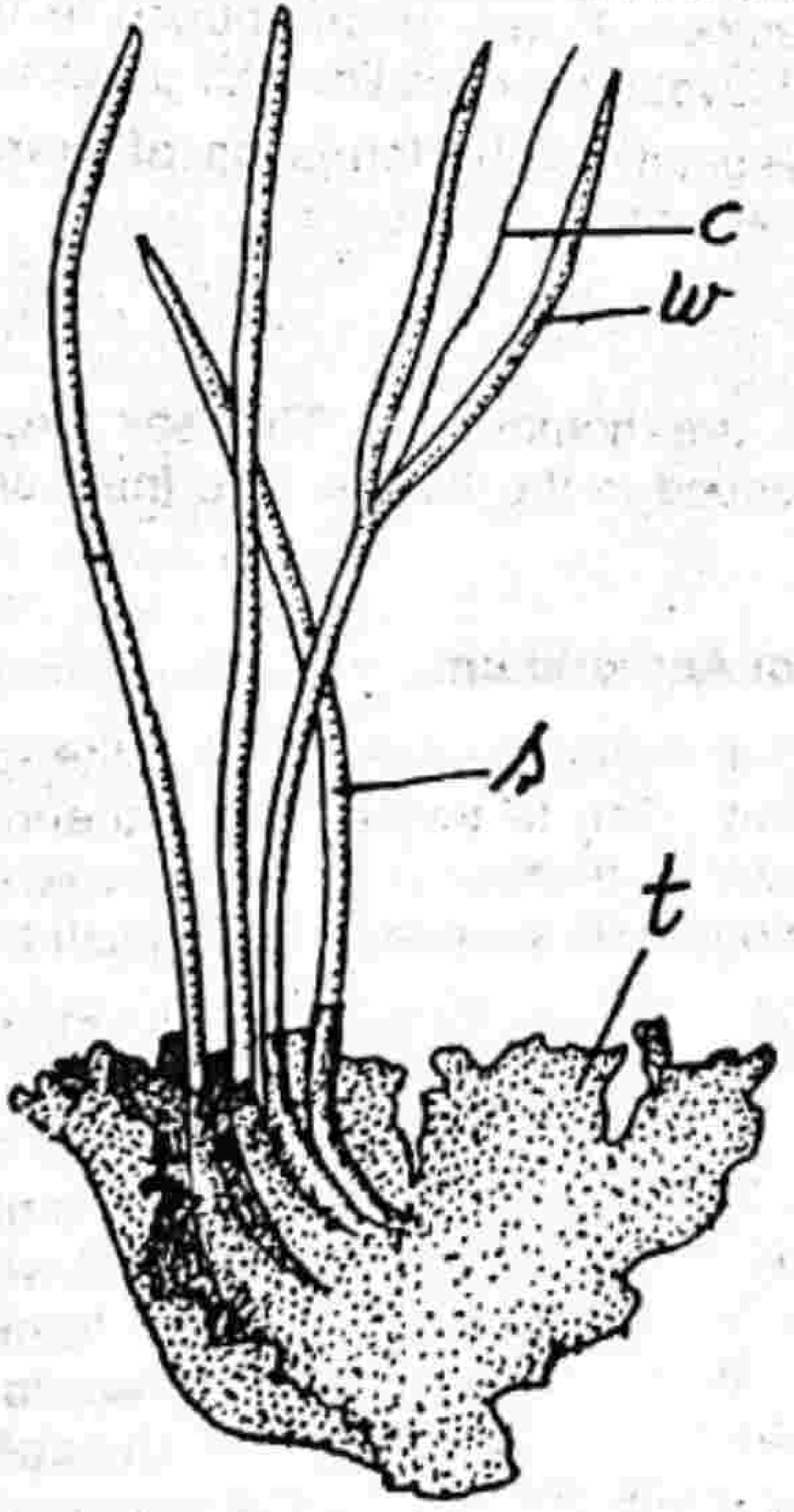


Fig. 6.10: Anthoceros — Vegetative morphology.

Internal Structure of the Thallus

There is no marked internal differentiation. The thallus comprises of parenchymatous cells. Each cell contains a single lens-shaped chloroplast, but deeply lying cells may contain 2-8 chloroplasts. A single pyrenoid is located within each chloroplast. The upper and lower surfaces are usually referred to as upper and lower epidermis. The lower surface of the thallus contain mucilage-filled cavities which open to the outside through a pore, the slime pore. These cavities contain blue-green alga Nostoc which fix free nitrogen.

REPRODUCTION — Gametophyte

The gametophyte reproduces by vegetative and sexual reproduction.

Vegetative Reproduction

Vegetative reproduction of thallus may take place by any one of the following methods:

i. By death of older cells of the thallus present away from the apex which result in separation of branches that grow into new plants.

ii. During unfavourable growth conditions, the margins of the thallus become thickened and swollen due to storage of food. These are called tubers. They are protected by formation of a corklike layer around them. These give rise to new thalli on return of favourable conditions for growth.

iii. In some species, the thalli die during hot summer except for their apices. These are called persistent apices. These remain buried in the soil and develop into new plants on return of favourable conditions for growth.

iv. Some species grow vegetatively by formation of gemmae produced on short stalks at the dorsal surface of the thallus.

Sexual Reproduction

Most *Anthoceros* spp are homothallic. The sex organs are antheridia and archegonia that develop embedded in the thallus. The thalli are protandrous, i. e., the antheridia develop first.

Structure and Development of Antheridium

The antheridia develop in roofed cavities called antheridial chambers present on the dorsal surface of the thallus. One to twenty five antheridia may develop in each antheridial chamber. A mature antheridium consists of an ovoid body and stalk. The body contains a mass of spermtogenous cells surrounded by a jacket of sterile cells.

A superficial dorsal cell of thallus divides transversely to form an inner cell that acts as antheridial initial, and an outer cell which is roof initial. A mucilage filled space develops between these initials. This space enlarges to form antheridial chamber. The roof initial divides anticlinally to form roof of the antheridial chamber. The antheridial initial divides to form primary antheridial cell and primary stalk cell which divide further to give rise to stalk of the antheridium. The primary antheridial cell divides by two vertical walls at right angles to each other to produce four cells. These cells undergo transverse divisions to form two tiers of four cells each. Periclinal division in the cells of these tiers separate eight inner primary androgonial cells and eight outer primary jacket cells which divide further anticlinally to form jacket layer. The primary androgonial cells undergo repeated divisions to give rise androcytes. Each androcyte divides diagonally into two cells, each of which metamorphoses into a biflagellate antherozoid or male sperms.

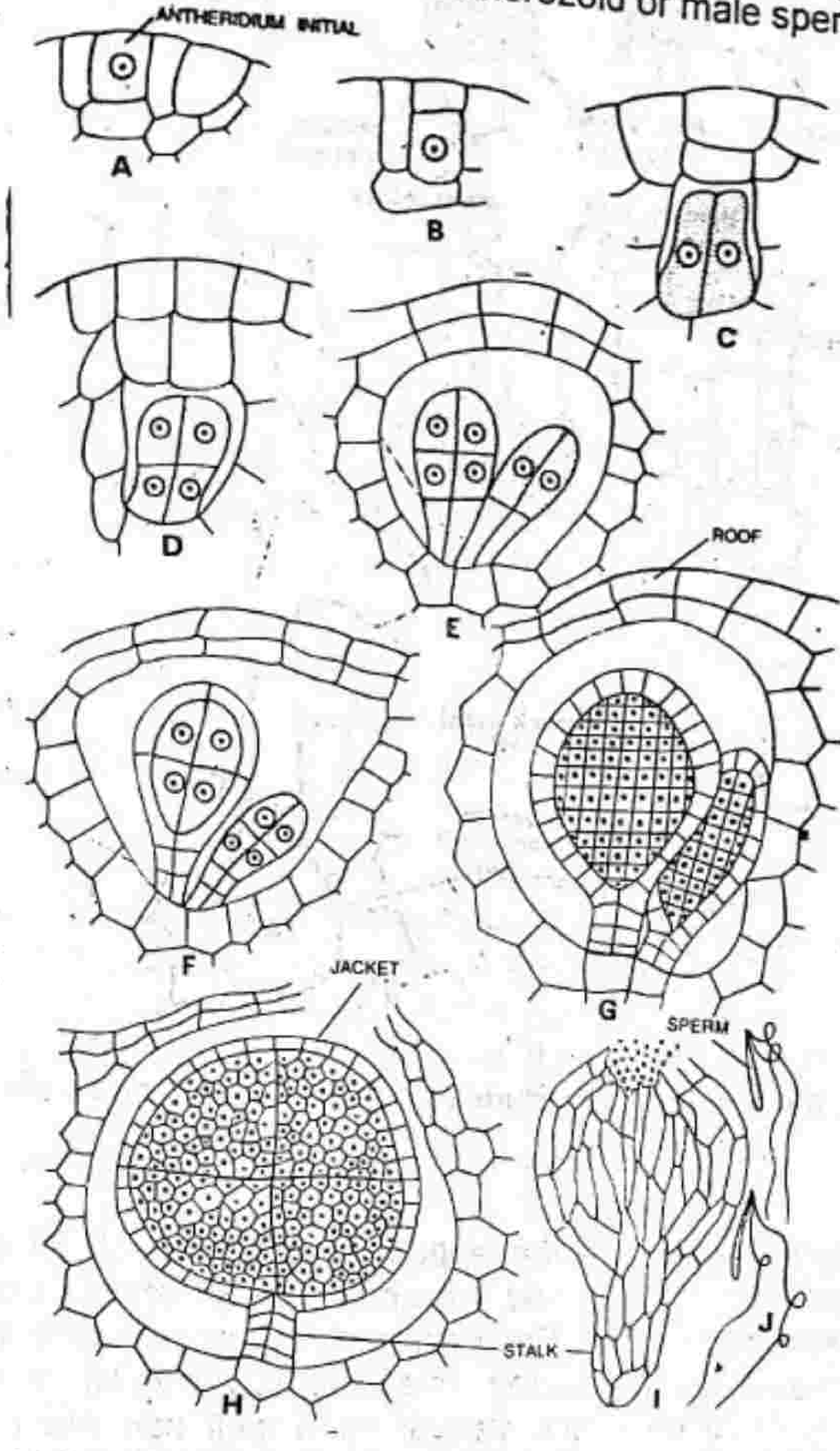


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Fig. 6.11.Anthoceros — Structure and development of antheridium.

Structure and Development of Archegonium

The archegonia develop embedded in the thallus and are in direct contact with vegetative cells. There is no jacket layer around the archegonium, only the neck is covered with cover cells. Each archegonium consists of an elongated neck containing an axial row of 4-6 neck canal cells; and a basal swollen portion, the venter that contains a ventral canal cell and an egg. The archegonium of *Anthoceros* resembles archegonium of some pteridophytes.

A surface cell of thallus act as archegonial cell directly. It divides by three intersecting vertical walls to produce three peripheral jacket initials surrounding an axial cell. The axial cell divides by a transverse division into cover initial which divides vertically to form four cover cells, and central cell. The central cell divides transversely into primary canal cell which gives rise to a row of 4-6 neck canal cells, and primary venter cell which divides to produce a ventral canal cell and an egg. The development of jacket layer is not clear.

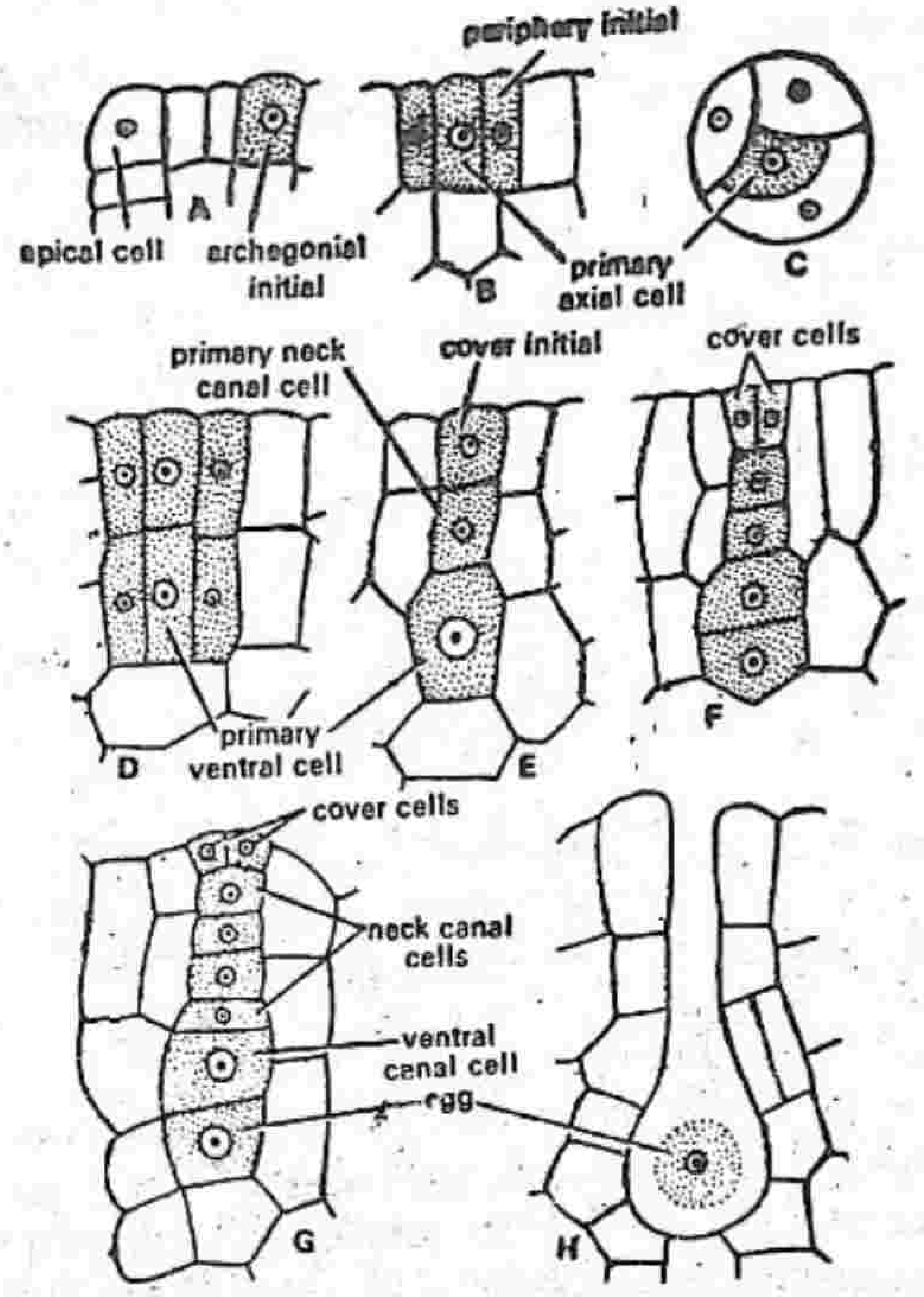

Fig. 6.12: Anthoceros — Structure and development of archegonium.

Fertilization

Upon maturation the roof of the antheridial chamber disintegrates to expose antheridia which absorb water, swell and the upper end of antheridial wall ruptures to release a mass of sperm mother cell. Each cell metamorphoses into a biflagellate male sperm within few minutes. At the same time, the cover cells of the archegonium disintegrate. The neck canal cells and ventral canal cell become mucilaginous. The mucilage oozes out and attract male sperms chemotactically. The male sperms swim to the archegonium and one of them succeeds in fertilizing the egg to form the zygote.

Post-Fertilization Changes

The zygote secretes a wall and start dividing to form embryo. At the same time the cells of archegonium and thallus tissue start dividing to form a protective sheath called calyptra around the developing embryo.

Asexual Reproduction — Sporophyte

The sporophyte phase of Anthoceros is represented by sporogonium in which asexual reproductive units, the spores are produced.

Structure of Sporogonium

The sporophyte or sporogonium of *Anthoceros* is unique as it has some features, which is different from other liverwort. The sporangium developed on the gametophyte but not depend on the gametophyte and it is semi-independent.

The sporangium consists of following parts.

Foot

A mature sporangium has a well developed inverted cup like foot. The food has rhizoid are the base.

Seta

There is no distinct stalk or seta.

Capsule

The upper part of the sporangium is capsule. It is a long narrow and cylindrical structure. The cell in the basal part of the capsule is meristematic; therefore, the upper part of the thallus is continuously grown in size.

Epidermis

The outer most layer of the cell is forms the epidermis, which contained cutinized wall. In the epidermis are small apertures or stomata, each having two guard cells.The stomatal aperture leads into the underlying intercellular spaces. The cell of the capsule wall contains chloroplast and can synthesized there own food. Therefore, sporophyte is not depend on the gametophyte but it is semi-independent

Collumella

In central part of the capsule is collumella. It is formed of 4 rows of elongated vertical row of cells. But later on it become 16 rows of cells.

Encircling the collumella is a narrow region which contains spores and elaters. The elaters has smooth or variously thickened wall. These elaters are also called as pseudo-elaters. The cells of the sporogenous tissues become arranged in alternate layers of larger and smaller cells. The larger cells are the spore mother cells each of which forms four spores after reductional division of nucleus.

The wall of the mature sporangium is several cell is several cell thick.The spores are liberated by rupturing of the wall at the top into two valves which become curled backward and twisted.

Germination of Spores

Each spore has black spiny wall called as exosporium and an inner wall endosporium. The spores undergo a period of rest of few weeks or months. After the period of rest, the outer wall ruptured and the inner wall protrudes out in the form of tube which become transversally septate and give rise the protonema. The cells after its activity give rise to the thallus.

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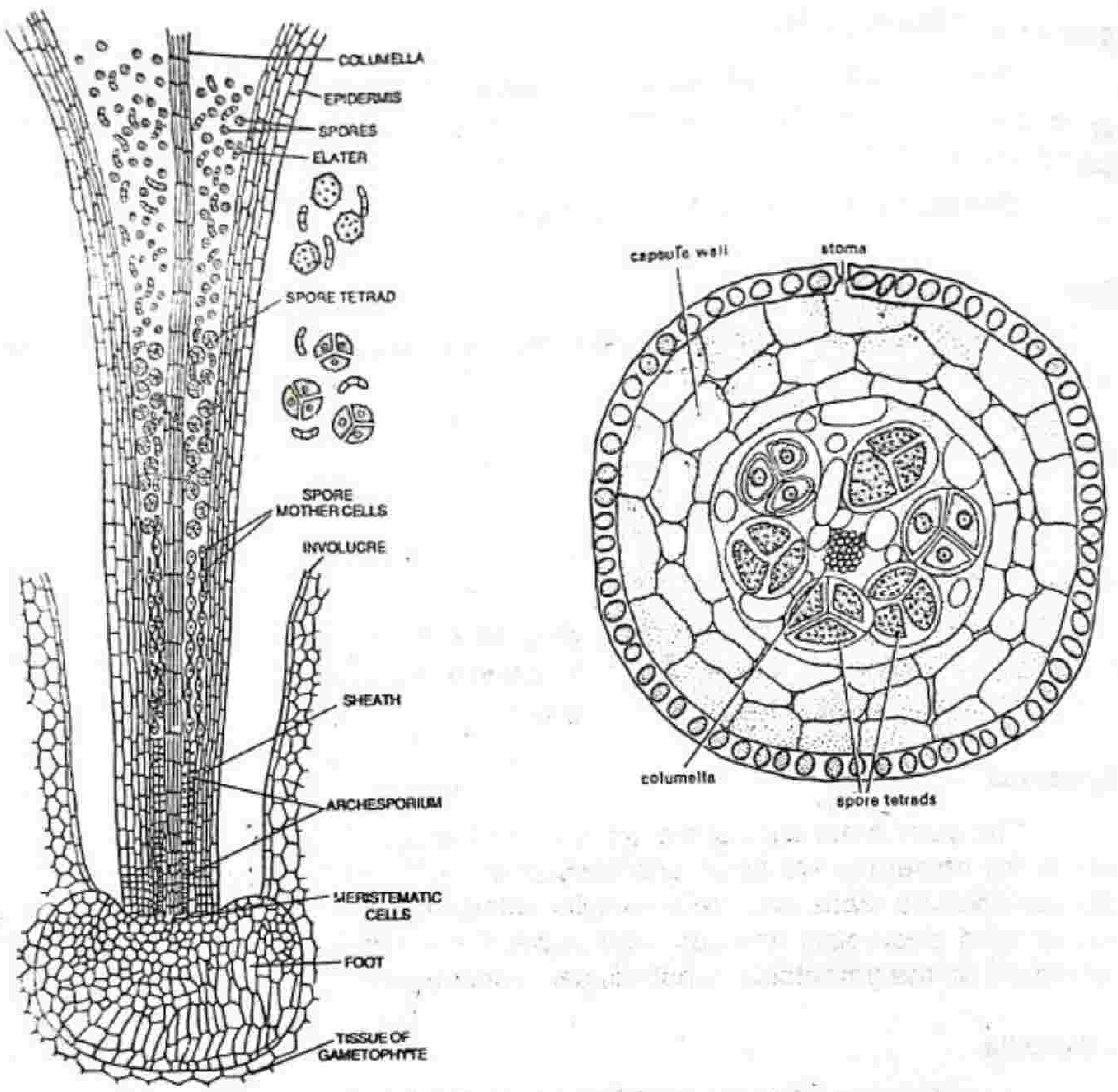

Fig. 6.13: Anthoceros — Internal structure of sporogonium.

Development of Sporogonium

The zygote divides by a vertical wall followed by a transverse division to give rise a quadrant-type embryo. The cells of the quadrant towards the neck are larger than the lower ones. A vertical division results in formation of 8-celled embryo consisting of two tiers of four cells each. The cells of lower tier divide by repeated divisions to form a bulbous foot. Rhizoid-like outgrowths arise from the foot which penetrate the gametophyte tissue, anchor the sporogonium and absorb nutrition.

The cells of upper tier develop into capsule. These cells divide by transverse divisions to form two or three tiers high column of cells. These cells undergo periclinal division to separate an outer layer of cells, the amphithecium; and an inner layer of cells, the endothecium which undergo sterilization to form columella. The cells of amphithecium divides periclinally to form jacket initials which divide further by periclinal divisions to give rise to the capsule wall, and primary sporogenous cells. The sporogenous cells overarch the columella and may extend to the base. The sporogenous cells divide into spore mother cells and sterile cells which join end to end to three to five cells high pseudoelators which help in dispersal of spores. The spore mother cells divide to produce tetrads of spores.

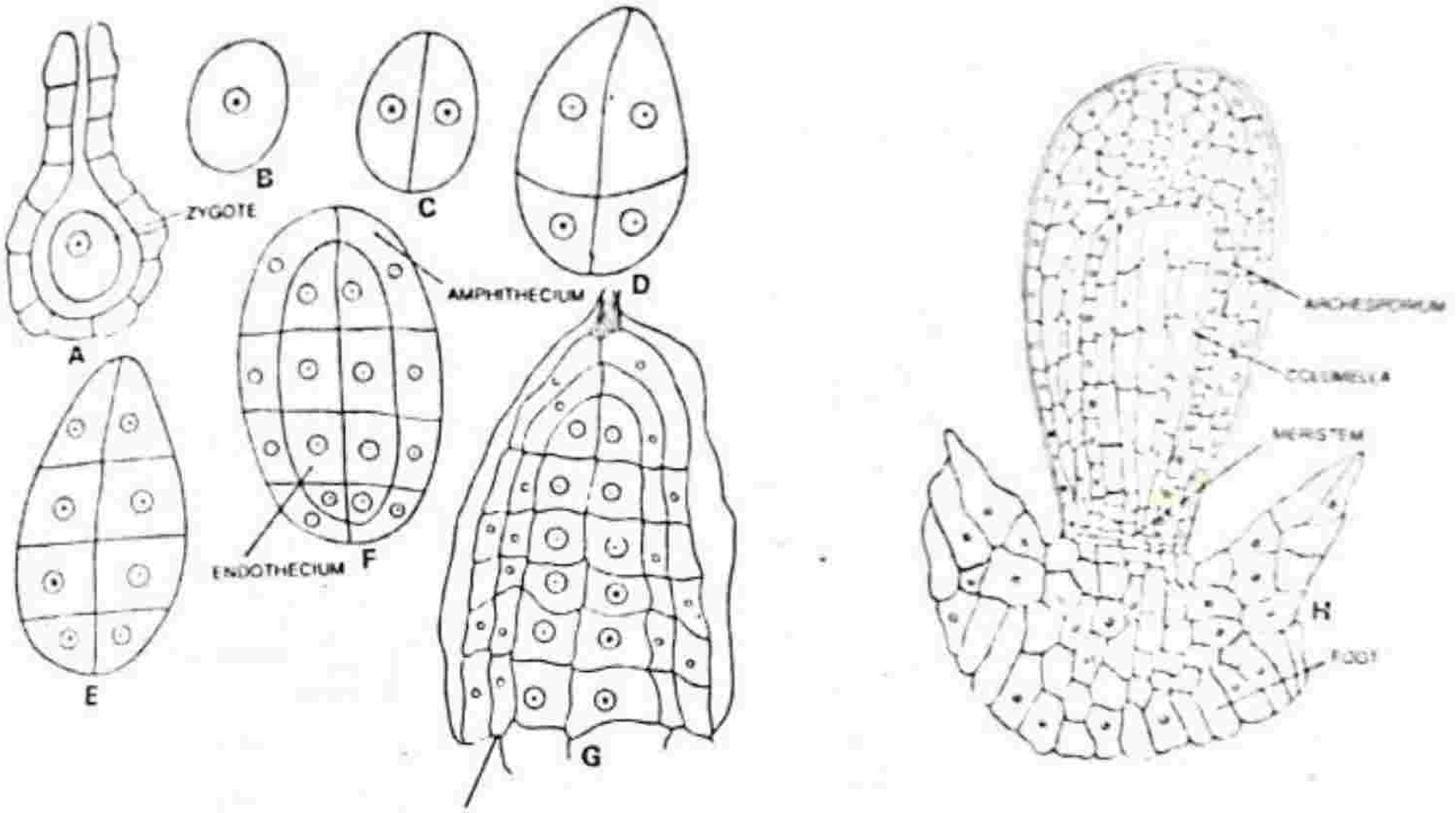

Fig. 6.14: Anthoceros — Development of sporophyte.

Germination of Spore and Development of Gametophyte

Each mature spore is tetrahedral and consists of protoplast surrounded by a two-layered wall, the outer exine and inner intine. The spore absorbs water and swells. The exine ruptures and the intine protrudes out to form a long germinal tube. The contents of the spore migrate into the tube and the plastids in it develop chlorophyll. Two apical cells are differentiated at the tip of germinal tube. The cells divide to produce eight cell, out which four cells act as growing point. The thallus develops by the activity of these cells. Any cell of the filament elongates to form first rhizoid. A mucilage slit develops close to growing point on the ventral surface. Nostoc cells penetrate through it and establish themselves in the mucilage cavities.

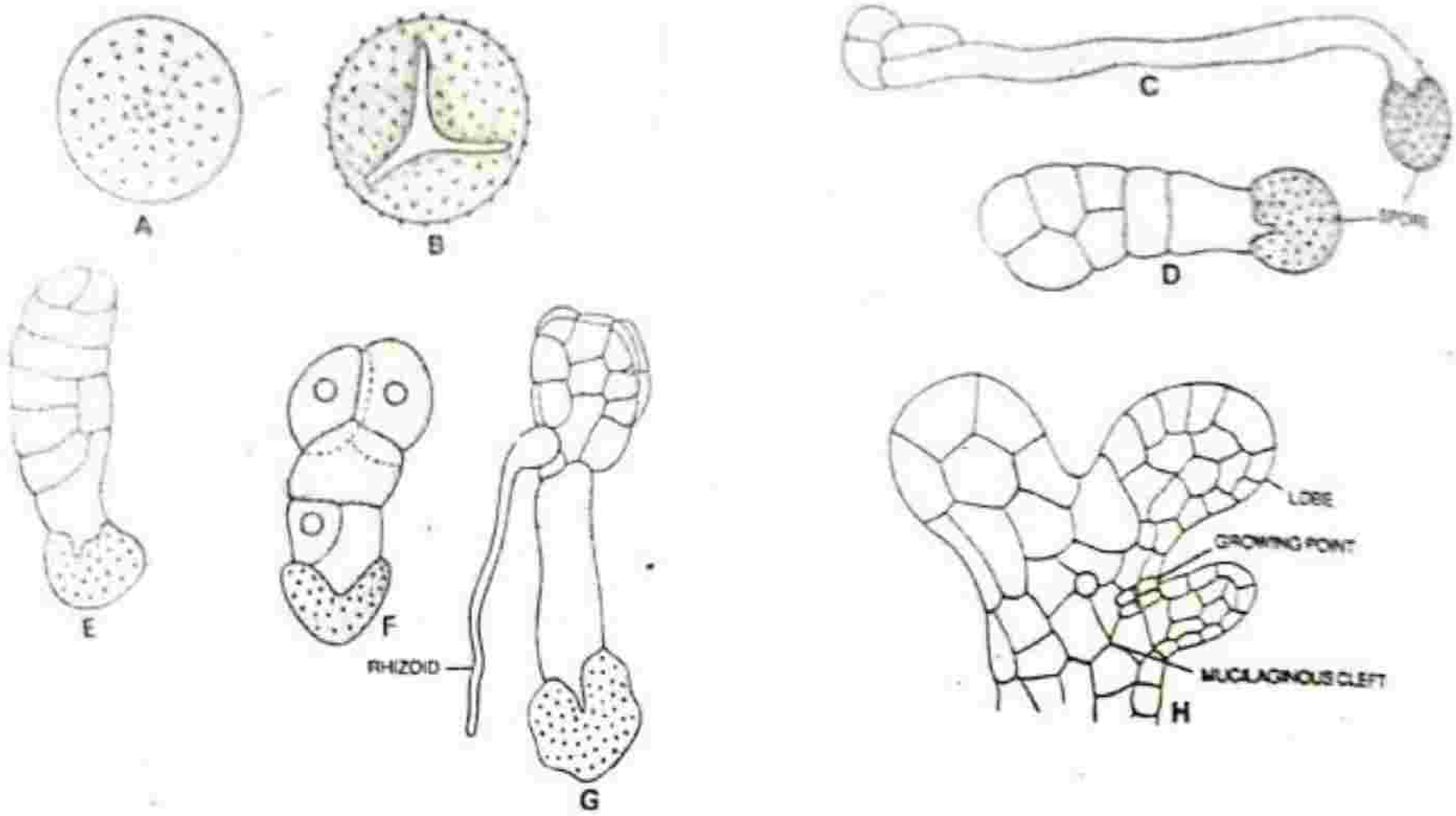

Fig. 6.15: Anthoceros — Development of gametophyte.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are anthocerotophyta.
2. What are systematic position of Anthocerous.
3. Define alternations of generations in Anthocerous.
4. Draw structure of thallus of Anthocerous .
5. Name two species of Anthocerous.
6. Describe vegetative reproduction in Anthocerous.
7. Draw structure of sporophyte of Anthocerous.
8. What is the importance of meristematic tissues in sporophyte of Anthocerous.

B. Long Questions

1. Describe asexual reproduction in Anthocerous.
2. Describe sexual reproduction in Anthocerous.
3. Describe sporophyte of Anthocerous.
4. What is alternations of generations. Describe life cycle of Anthocerous.
5. Describe structure and reproduction of gametophyte of Anthocerous.
6. Describe sporophyte of Riccia and compare it with sporophyte of Anthocerous.

BRYOPSIDA

The class includes true mosses. About 14,000 species allotted to nearly 650 genera are included in the class. About 90% of the species are mosses. The most common genera included in the class are: *Funaria, Polytrichum* etc.

General Characteristics

The chief characteristics of the members included in the class are:

i. The body is characteristically divided into stem and leaves. The stem may be erect or prostrate; and the leaves are either small green outgrowths or may be flat or expanded.

ii. Internally the stem exhibits tissue differentiation but no true vascular tissue is developed.

iii. The sex organs are either produced on separate plants or on separate branches, at the apex of the branch. These are surrounded by a group of leaves.

iv. The sporophyte consists of a stalk and capsule in which spores are produced.

v. The capsule is specialized and possesses stomata and chloroplasts.

vi. The spores on germination give rise to a filamentous structure, the protonema. Numerous shoots arise from it which compose the mature moss plant.

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FUNARIA

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Systematic Position

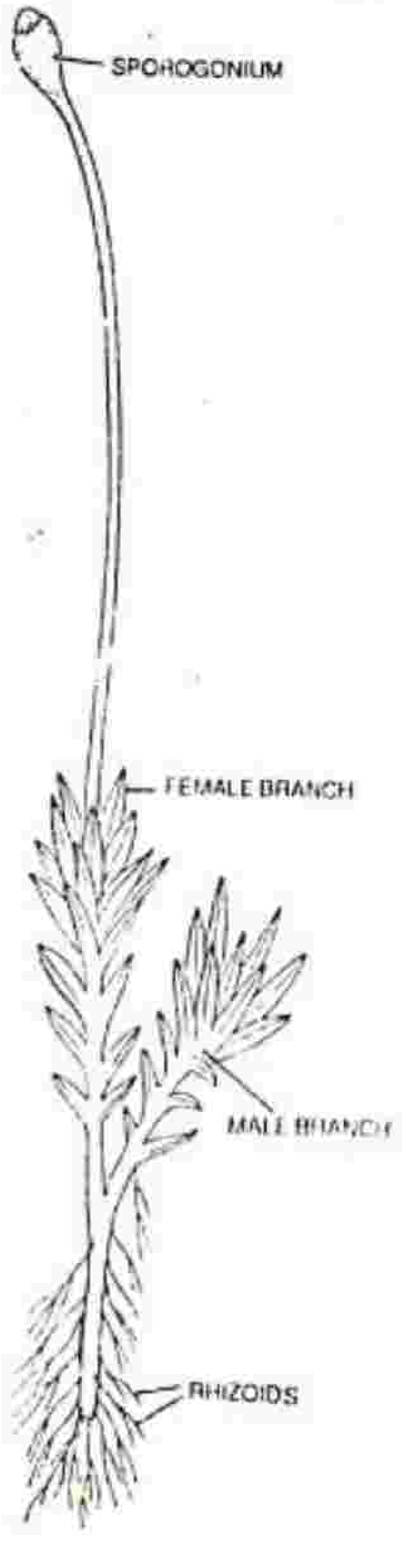
Division:	Bryophyta
Class:	Bryopsida
Order:	Funariales
Family:	*Funariaceae*
Genus:	*Funaria*

Funaria is a common terrestrial moss which grows in the form of bright green velvety patches in shady and damp places. The genus comprises of 117 species. *Funaria hygrometrica* is most common and worldwide species. It colonizes burnt soil and grows best in the presence of calcium, potassium, nitrogen and phosphorus.

Vegetative Morphology

(✓.✓)

Funaria plant is a gametophyte and the plant body is differentiated into a prostrate, green, branched filamentous structure, the protonema which gives rise to erect leafy shoots called gametophores. Protonema is short-lived, therefore a transitory structure. The adult plant consists of gametophores only. Each gametophore is differentiated into stem and leaves. They bear sex organs at their apices. Rhizoids arise



from the base of each gametophore which anchor it into the soil and absorb moisture and nutrients. The leaves are small, ovate, sessile and green. The leaves borne on prostrate branches and on lower portion of erect branches are colourless and scale-like.whereas the leaves on upper portion of an erect branch are green and larger in size. These are called foliage leaves and are spirally arranged. The leaves also surround sex organs. These leaves are larger in size and different in shape.

REPRODUCTION — Gametophyte

Funaria gametophyte reproduces by vegetative multiplication and sexual reproduction.

Vegetative Multiplication

The vegetative multiplication takes place in a variety of ways, such as:

i. The prostrate branches die and erect branches grow as independent plants.

ii. Small gemmae develop in groups along the midrib of leaves or at the tips of stem. Each gemmae develop into a new plant.

iii. A spore germinates into primary protonema which break up into fragments by death of cells. Each fragment develops into a new protonema, form buds and give rise to gametophores.

iv. In some cases the sporophyte tissue is wounded and produce a protonema. The buds develop on it and each bud grows into a diploid gametophore. This is called as apospory.

Sexual Reproduction

Funaria spp are monoecious. The sex organs, antheridia and archegonia develop at the apices of separate erect branches called gametophores. The sex organs are intermingled with 4-6 cells high and one cell wide sterile hairs called paraphyses. The paraphyses cells contain chloroplasts and the apical cell of each paraphyses is globose and meet over an antheridium to protect it. The paraphyses also hold water by capillary and help prevent desiccation.

Male Branch

Antheridia develop in group at the expanded convex-shaped apex of a leafy gametophore called male branch. The antheridia are intermingled with paraphyses.

Structure and Development of Antheridium

A mature antheridium is club-shaped and borne on a stalk. The main body contains a mass of spermatogenesis cells surrounded by a layer of jacket cells. The free distal end of the antheridium is differentiated into a caplike structure, the operculum. It helps in dehiscence.

Each antheridium develops from a superficial cell of apex which becomes papillate and divide to form an outer and an inner cell which gives rise to lower embedded part of the stalk. The outer cell divides by transverse divisions to produce a filament of 2-3 cells. The terminal cell of the filament differentiate into apical cell with two cutting faces. It cuts off 5-15 segments arranged in two rows. A segment, 2-3 cells away from the apical cell, divides into a smaller jacket initial and a larger primary spermatogenous cell which cuts off a second jacket initial. The jacket initials divide anticlinally to form a single layered jacket. The primary spermatogenous cells undergo repeated divisions to produce sperm mother cells. Each sperm mother cell metamorphoses into a biflagellate male sperm. The apical cell differentiates into operculum.

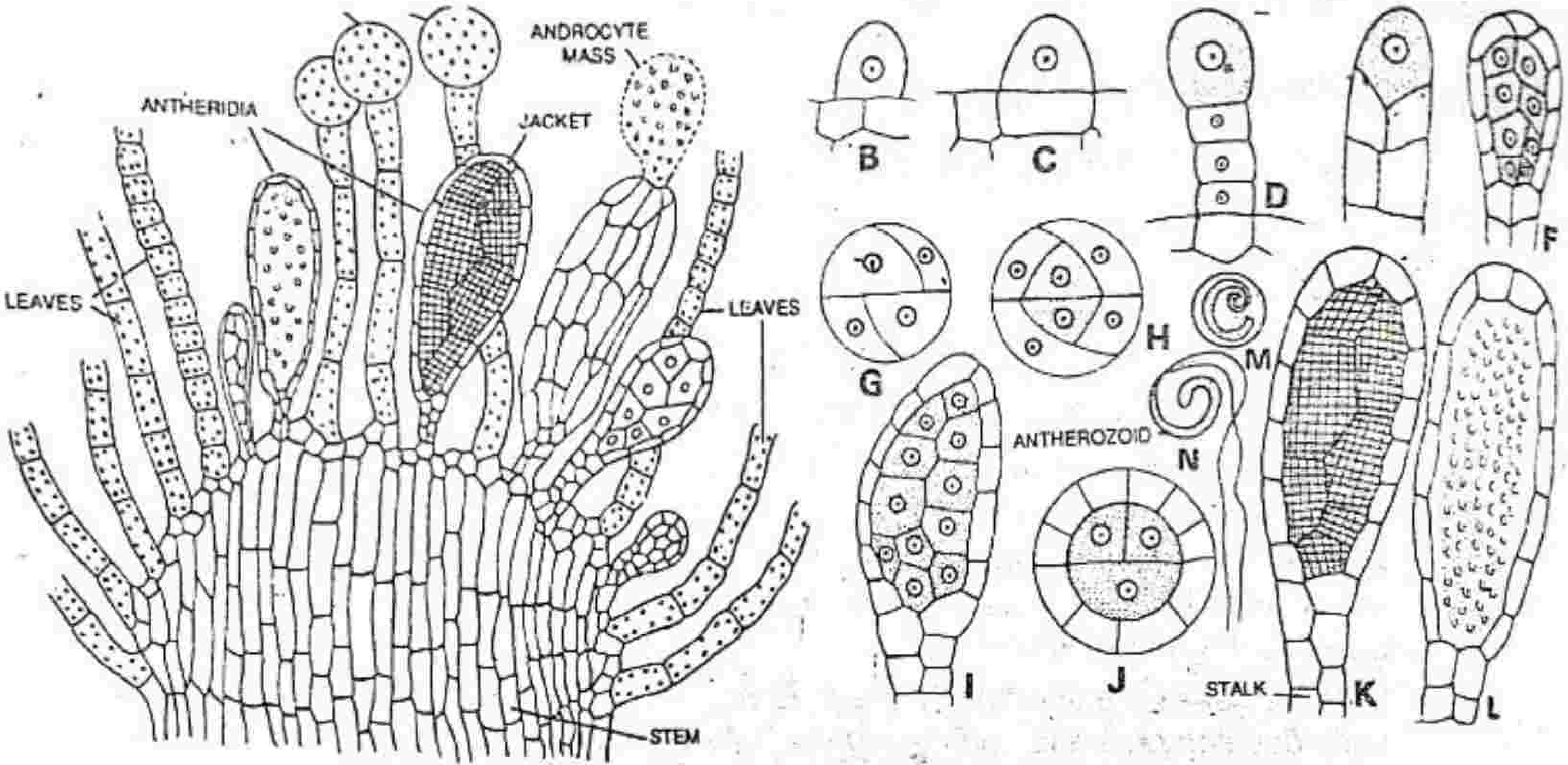


Fig. 6.16: Funaria — Apical portion of a male branch and development of antheridium.

Female Branch

The gametophore bearing archegonia is called female branch. It arises from the base of male branch. The apex of the branch flattens into a receptacle on which archegonia develop in clusters intermingled with paraphyses.

Structure and Development of Archegonium

A mature archegonium is flask-shaped which is borne on short stalk. It has a basal swollen part, the venter, and elongated neck. The venter is surrounded by a two-layered jacket whereas the jacket around the neck is single layered.

Archegonium develops from an apical cell with two cutting faces. It cuts off 4-8 segments which develop into stalk. Afterwards the apical cell becomes three sided and cuts off three peripheral cells surrounding an axial cell (the former apical cell). The peripheral cells divide to form jacket initials which divide to form jacket layers around the venter and neck. The axial cell divides to form primary cover cell and central cell which divides to form primary canal cell which give rise to neck canal cells, and venter cell. The venter cell divides to produce venter canal cell and an egg.

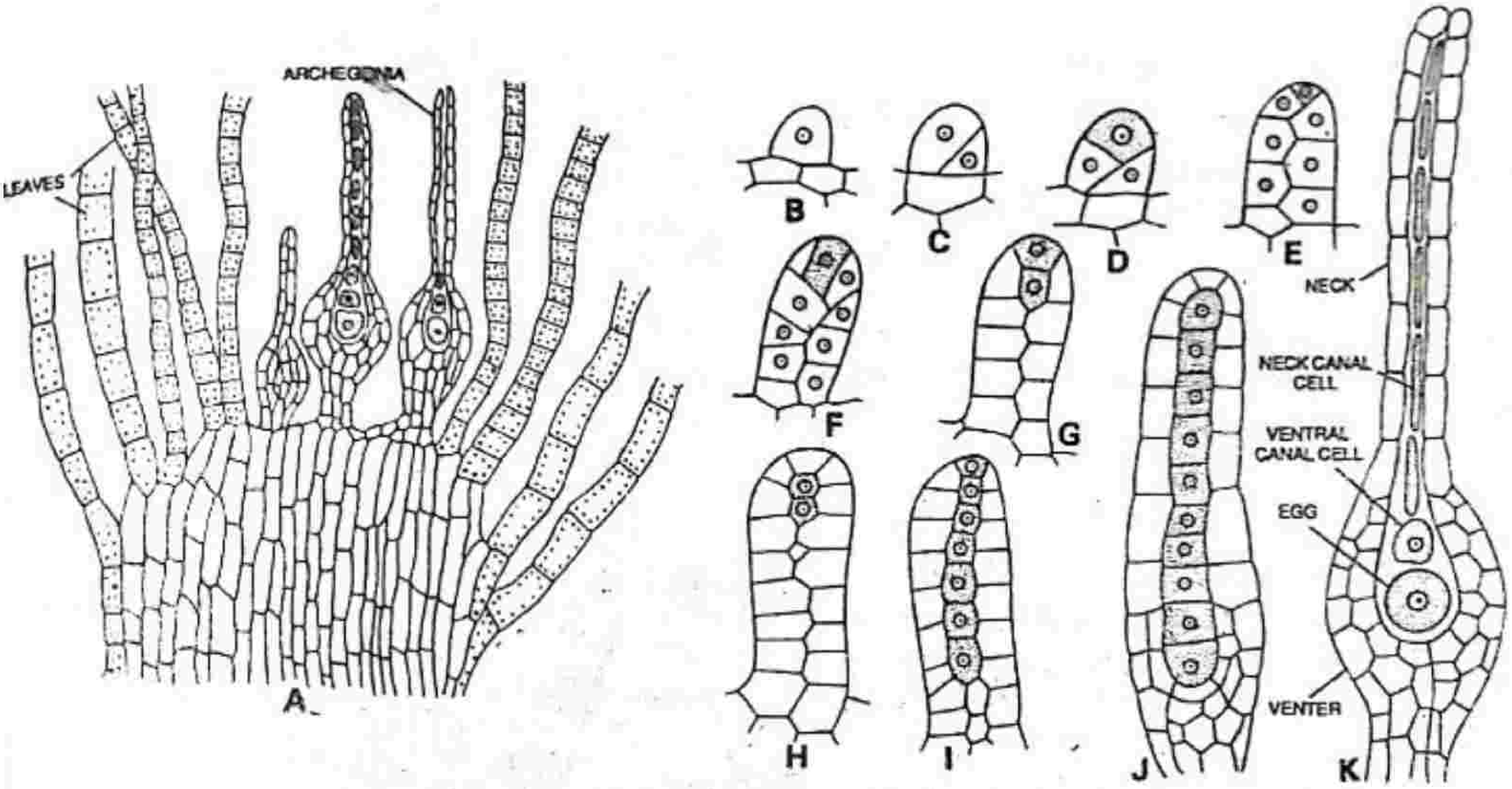


Fig. 6.17: Funaria — Apical portion of female branch and development of archegonium.

Fertilization and Post-Fertilization Changes

Rain water or dew drops collect at the apical end of the male branch cause dehiscence of antheridium. The jacket cells imbibe water and split open at operculum forming a pore. The male sperms move out in a mass. At the same time neck canal cells and venter canal cell disintegrate to form mucilage. It absorbs moisture, swell up and forces disintegration of apical cells of the neck. The male sperms are attracted chemotactically, swim to archegonium, enter it and one of these succeeds in fertilizing the egg to form the zygote.

The zygote enlarges in size to fill up the venter and secretes a thick wall around it. The stimulus of fertilization initiate divisions in the cells of venter which form protective sheath called calyptra around the developing sporogonium.

Sporogonium

The sporophyte in Funaria is commonly called sporogonium. The asexual reproductive units, the spores, are produced in it. Meiosis takes place before spore formation.

Structure of Sporogonium

A mature sporogonium is borne at the end of a female branch. It can be differentiated into a massive foot, a long seta, and a pear-shaped capsule. The foot is embedded in the apical tissue of female branch. It absorbs water and nutrients from the gametophyte. The seta is a long stalk that carries capsule at its apex. The capsule is pear-shaped highly organized spore-producing structure. The young capsule is green but as it matures it turns dark brown. The apical part of the capsule is covered with remains of ruptured calyptra. The capsule exhibits considerable tissue differentiation.

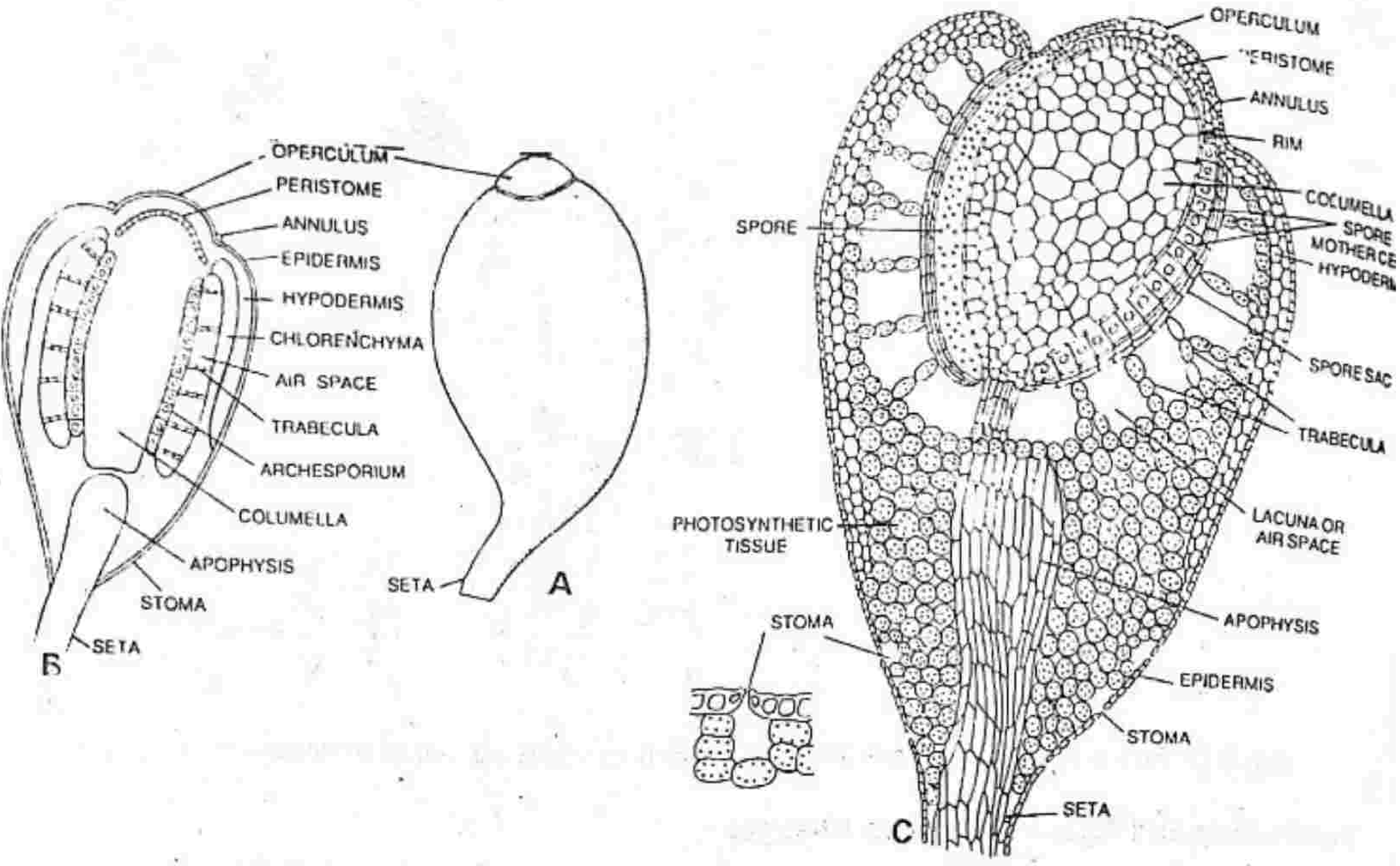


Fig. 6.18: Funaria — Morphology and Internal structure of sporogonium.

Internal Structure of Sporogonium

The foot is bulbous mass of tissue embedded in the apical tissue of the female branch. The seta consists of a central conducting strand composed of thin-walled cells surrounded by cortex and epidermis which is covered with cuticle.

The capsule is differentiated into three regions, the apophysis, theca and operculum.

i.Apophysis:

It is slightly swollen basal sterile region of the capsule. The wall consists of epidermis that contains stomata. Beneath it is photosynthetic spongy layer formed of parenchyma cells with intercellular spaces. The center is occupied by a strand of thin-walled, vertically elongated cells that are conducting in nature.

ii.Theca:

It is central part of the capsule and is characterized by presence of sterile central column of tissue called columella. It is surrounded by barrel-shaped spore sac that contains spore mother cells. Outer to spore sac there is a wide air space traversed by transverse strands called trabeculae which connect the capsule wall to the wall of the spore sac. The wall of the theca consists of epidermis, hypodermis and two cells thick photosynthetic spongy layer.

iii. Operculum:

The operculum is conical and cap-like terminal region of the capsule. It consists of 3-4 layers of thin-walled cells covered with epidermis. Immediately below the operculum is peristome. It is a ring of tooth-like segments. It is double consisting of 16 long, incurved teeth and 16 thin-walled inner segments. The peristome is attached to a ring of thin-walled cells that form rim of the capsule. The peristome teeth are hygroscopic and respond to slight changes in humidity.

The region of capsule above the theca consists of 4-5 layers of epidermal cells. The lower two layers of cells are thin-walled and constitute annulus. The degeneration of annulus cells results in loosening and dropping off of operculum.

Development of Sporogonium

The zygote enlarges and divides by a transverse division into an upper epibasal and a lower hypobasal cell. Both these cells divide by two oblique divisions to produce two apical cells. The segments cut off from upper apical cell mature into capsule and upper part of the seta, and the segments cut off from lower apical cell develop into lower part of seta and foot.

The segments cut off by upper apical cell divide vertically and appear as a quadrant in transverse section. A vertical wall perpendicular to an inner cell results in formation of a triangular and a rectangular cell in each quadrant. The four rectangular cells divide by a periclinal wall to produce a 4-celled endothecium surrounded by an 8-celled amphithecium. These layers act as fundamental embryonic layers of the sporogonium.

In the theca region of the capsule, the endothecium cells divide first by a curved vertical wall to separate a triangular and a rectangular cell and then by a periclinal wall to produce four central cells and a ring of eight peripheral cells. The central cells divide and differentiate into central columella. The peripheral cells divide periclinally into an outer layer, the cells of which divide repeatedly to form sporogenous tissue (archesporium);, and inner layer of cells which give rise to inner spore sac.

The cells of amphithecium divide periclinally to separate outer and inner layers of eight cells each. The inner layer is called first ring and its cells divide and mature into outer spore sac. The cells of outer layer divide anticlinally first and then periclinally to produce an inner 16-celled second ring, the cells of which give rise to trabeculae. The cells outer to second ring divide again anticlinally first and periclinally later to produce a 32-celled inner third ring, the cells of which differentiate into spongy layer. The cells external to third ring divide periclinally to separate 32-celled each, fourth and fifth ring. The cells of these rings differentiate into hypodermis and epidermis respectively.

In the apical region of capsule, the endothecium cells undergo anticlinal and periclinal divisions to produce five concentric rings of cells comprising of 8, 16 and 32 cells. The cells of first and second ring differentiate into peristome. The cells of third and fourth ring form thin-walled tissue of the operculum while the cells of fifth ring give rise to epidermis. The epidermal cells at the base of operculum enlarge to form annulus.

In region of apophysis, the endothecium cells divide repeatedly to form conducting strand. On the other hand, the cells of amphithecium divide by anticlinal and periclinal divisions to produce five concentric rings of cells. The cells first four rings differentiate into spongy zone while the cells of the fifth ring give rise to epidermis.

Dehiscence of Capsule and Dispersal of Spores

During ripening of the capsule, the thin-walled operculum cells below the epidermis and at the base of annulus, begin to dry and shrivel. This results in a loose connection between operculum and underlying tissue. Finally the operculum is shed exposing the peristome. Teeth of the peristome exhibit pronounced hygroscopic movements. In dry weather they bend outward and pave the way for spores to move out of the capsule. However, in moist weather they bend down over the spore sac preventing the dispersal of spores. Thus, peristome regulates the dispersal of spores.

Germination of Spores and Development of Protonema

A spore starts germinating immediately after it is shed from the capsule. The spore increases in size and the outer spore wall ruptures. The inner spore wall grows out into one or two germ tubes. Each germ tube is separated from the spore by the formation of a cross wall near its point of emergence. The cell cut off soon develops into a branched multicellular filament, the protonema.

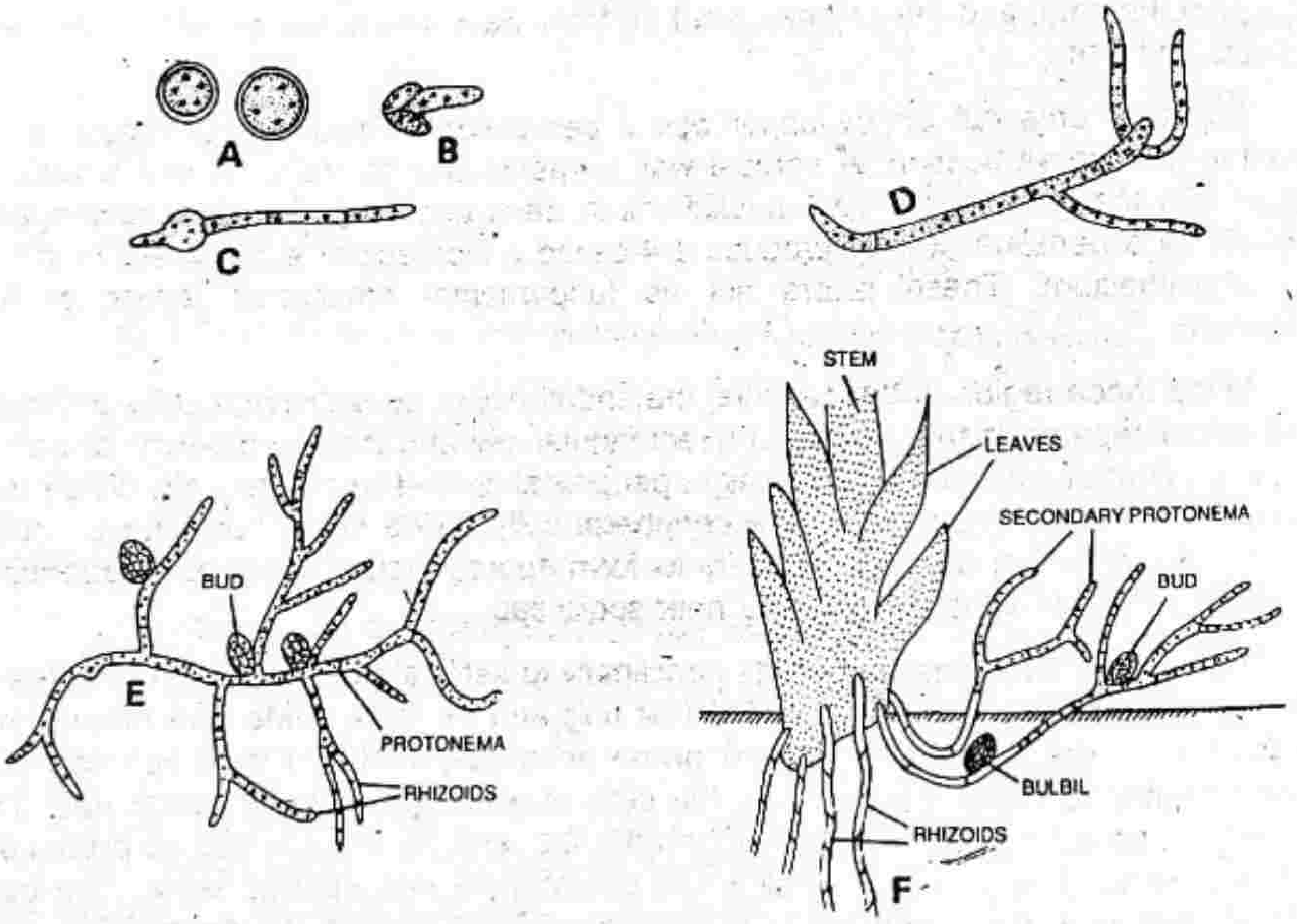


Fig. 6.19: Funaria — Development of gametophyte.

POLYTRICHUM (Hairy Cap Moss)

Systematic Position

Division:	Bryophyta
Class:	Bryopsida
Order:	Bryidae
Sub-order:	Polytricales
Family:	Polytrichaceae
Genus:	*Polytrichum*

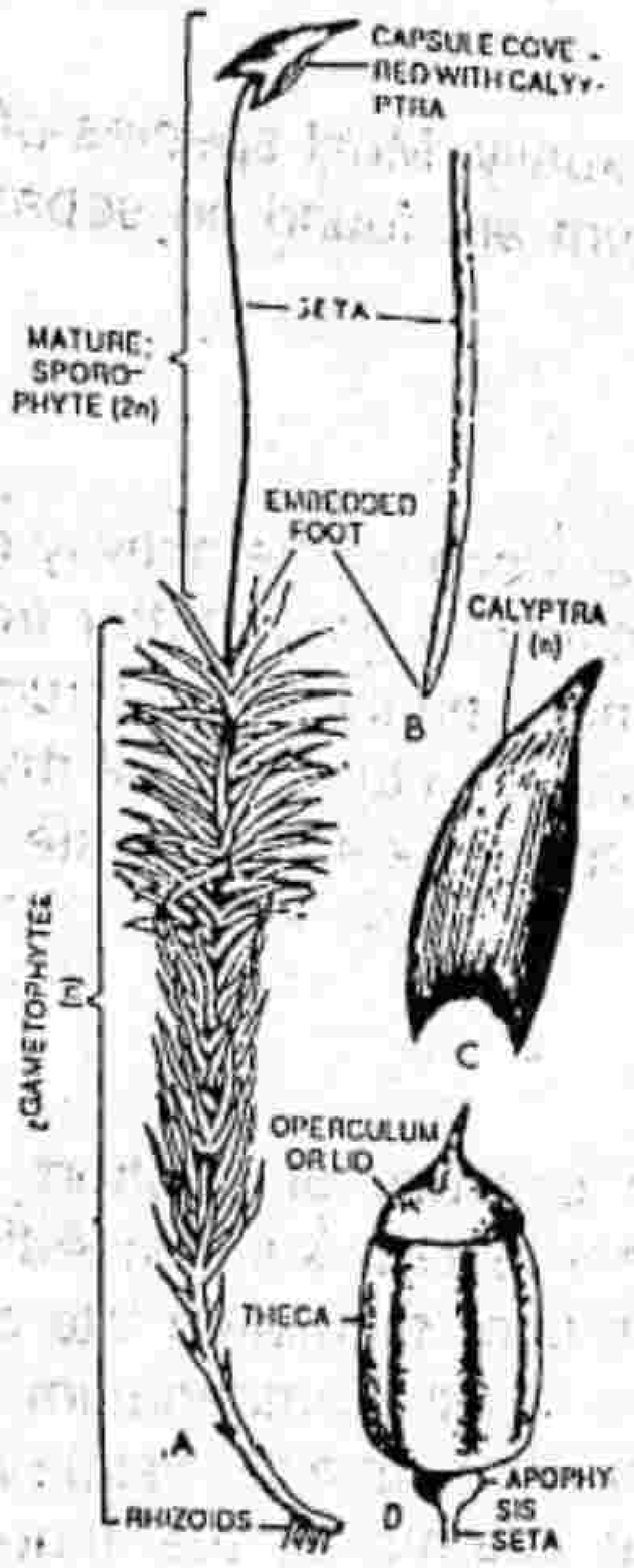


Fig. 6.20: A Polutrichum Gametophyte & Sporophyte

Occurrence:

Polytrichum has 92 species. They are found in tropical and cool temperature zones. Like other mosses, it also prefers cool and shady places and grows on damp soil, moist rocks, under shades sandy grounds banks etc. *Polytrichum densifolium*, *Polytrichum juniperinum* and *Polytrichum xanthophilum*are well known specie.

PLANT BODY

The plant body is differentiated into the following regions

1.Rhizoids

The rhizoids are more or less long, branched, thick walled obliquely septate, multicultural thread like structure. They arises from the rhizome

2.Rhizome

The rhizome is an underground portion from which arise aerial leafy shoots.

3.Aerial Shoots

The aerial leafy shoots arise from the rhizomes. This shoot may be 20-25 cm in height.

4.Leaves

The leaves present on the rhizome appear colorless and are called as scale leaves. The leaves on the aerial shoots relatively large, thick, rigid and borne on the axis.Each leaf has a broad, colorless, membranous sheathing base.

Reproduction

Plant reproduces by sexually. Most species of the *Polytrichum*are dioecious and the antheridium and archegonium are found on separate plant.They arise at the tips of leafy gametophores in groups.

Male Gametophore

A group of antheridia develops by the activity of apical cell of male gametophore. The leaves surrounding the antheridial group differ from vegetative leaves in that these are coloured and are modified into a perianth-like structure. It appears like an open flower and considered to be a compound structure. Sterile multicellular hair-like paraphrases are present among the antherdia. It has been suggested that these prevent drying of sex organs.

Structure of Antheridium

A mature antheridium consists of a short stalk and club-shaped body that contains a mass of spermatogenous cells surrounded by a single layered jacket of sterile cells. The tip of the antheridium is differentiated into operculum consisting of 4-5 tiers of small cells with thickened walls. As the antheridium mature a fluid accumulates at the base of antheridium between spermatogenous tissue and sterile jacket. This fluid acts as hydraulic ram and forces out sperms at the time of release of sperms from the antheridium.

Development of Antheridium

Each antheridium develops from a superficial cell at the apex of gametophore. It becomes papillate and divides by a transverse wall. The outer daughter cell develops into antheridium except for the embedded part of the stalk. The outer cell divides transversely to form a filament of two to three cells in length. The terminal cell of this filament acts as apical cell with two cutting faces. It cuts off 5-25 segments. Each segment divides in a diagonally vertical plane to give rise to first jacket initial and the second daughter cell divides to produce second jacket initial and primary spermatogenous cell. The jacket initials divide perclinally to give rise to jacket, whereas the primary spermatogenous cell divides repeatedly to produce sperm mother cells. Each sperm mother cell metamorphoses into a coiled, flagellated male sperm.

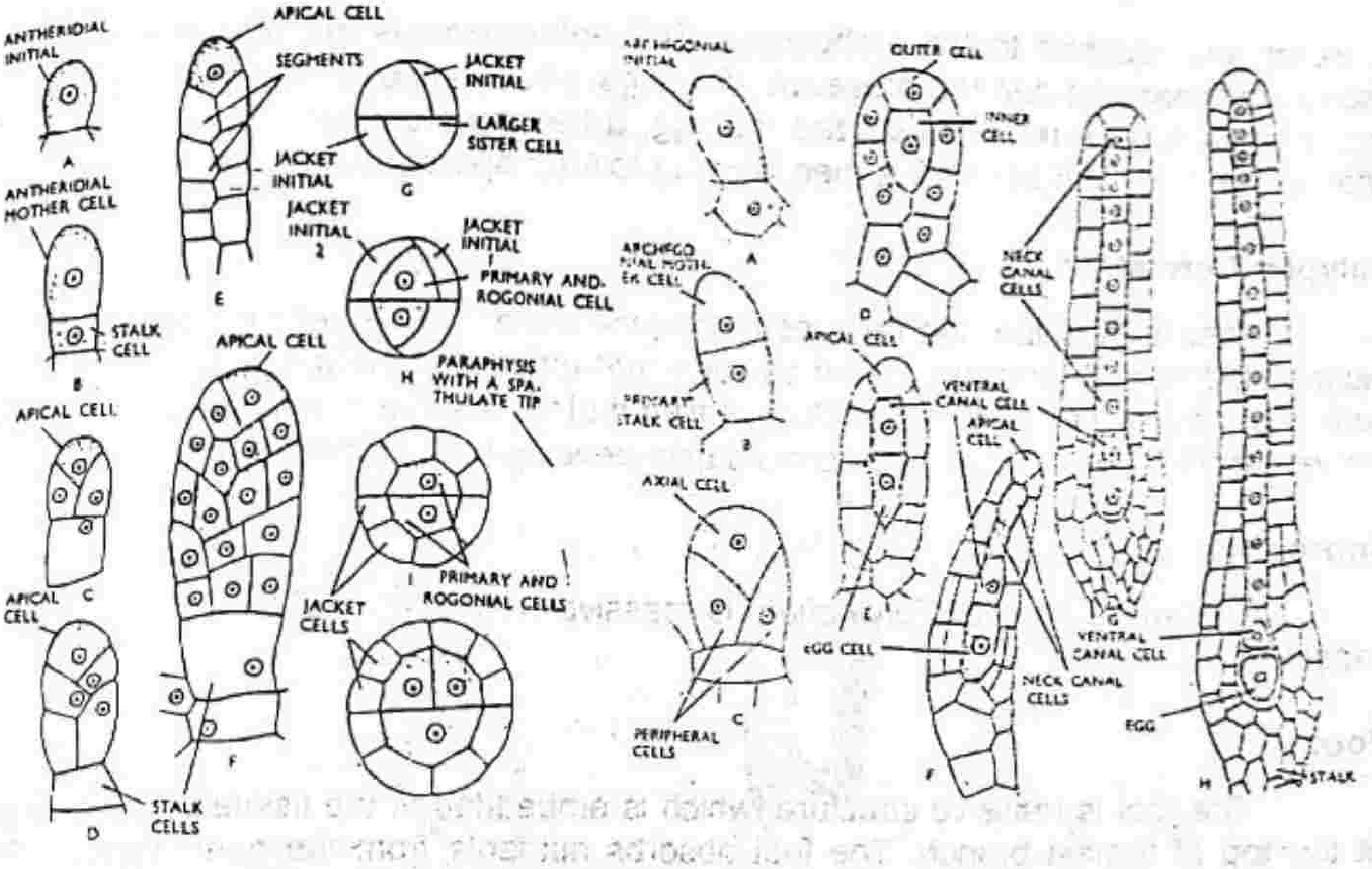


Fig. 6.21: Anthredium and Archegonium

Female Gametophore

Archegonia develop in groups at the tip of female gametophore. The group of archegonia is surrounded by perichaetial leaves, which overlap them to form a bud-like structure, the perichaetium. Like antheridia, paraphrases are also present intermingled with archegonia.

Structure of Archegonium

A group of 3-6 archegonia develop at the apex of female gametophore. Each archegonium has an extremely long, often twisted neck and a basal swollen portion called venter. The neck is composed of six vertical rows of cells and contains a series of neck and cells. The venter contains ventral canal cell and a single egg. It is attached to the female gametophore through a stalk.

Development of Archegonium

Each archegonium develops form an apical cell of female gametophore with two cutting faces that cuts off 4-8 segments that divide repeatedly to produce stalk of the archegonium. Later the apical cell develops three cutting faces. A segment is cut off from each of three faces to produce three peripheral initials surrounding an axial cell. The peripheral initials divide vertically to produce jacket initials that undergo periclinal divisions to form jacket. The axial cell divides by transverse division to give rise to primary cover cell and a central cell. The central cell divides transversely into a primary canal cell and a venter cell. The primary cover cell contributes to the jacket layer of the neck and neck canal cells. The venter cell divides to produce ventral canal cell and egg.

Fertilization

Fertilization takes place when the plants are wet with water. The biflagellate antherozooids are released by rupturing the antheridial wall. The antherozooids are swim in water and reached to the archegonia. The antherozooids are attracted towards the necks of archegonia due the presence of a sugary substance in the mucilage. One of the sperm enter the venter and fertilized the egg. It becomes oospore by secreting the wall after fertilization. The oospore is then growing to form sporophyte.

Calyptra Formation

After fertilization, the cells near the junction of the venter and its stalk undergo rapid divisions and form an inflated calyptra that encloses young saprophyte. The major portion of calyptra is composed of thick-walled protonema-like branches, which arise from the venter after fertilization and expand during development of the saprophyte.

Sporophyte

The sporophyte of *Polytrichum* is massive well differentiated into foot, seta and capsule.

Foot

The foot is massive structure, which is embedded in the tissues of gametophyte at the top of female branch. The foot absorbs nutrients from the gametophyte. These nutrients are conducted to the capsule through the central region of the seta.

Seta

Seta is a long structure, which is present on the foot. The sporangium is raised above due to the presence of long sets. The seta has conducting strands through which the food is transported.

Capsule

The young capsule is green and oval in shape with a conical cap at the top. The young capsule and the seta are green in color and can manufacture their own food therefore, the sporophyte is semi dependent on gametophyte.

The capsule consists of three distinct zones

1. Apophysis, 2. Theca, a spore bearing zone, 3. An operculum

Apophysis

The basal part of the capsule is sterile and is called as apophysis. The cells of apophysis are rich in chloroplast and are the main photosynthetic tissues. The wall of apophysis also contains stomata like aperture.

Theca

The theca is middle part, exhibits distinct ridges giving it a polygonal appearance. The wall is composed of several layer of chlorophyll cells. The outer most layer of wall is differentiated into an epidermis, of which the cells posses thickened outer wall. An outer lacuna (Air spaces), are present in the inner wall.

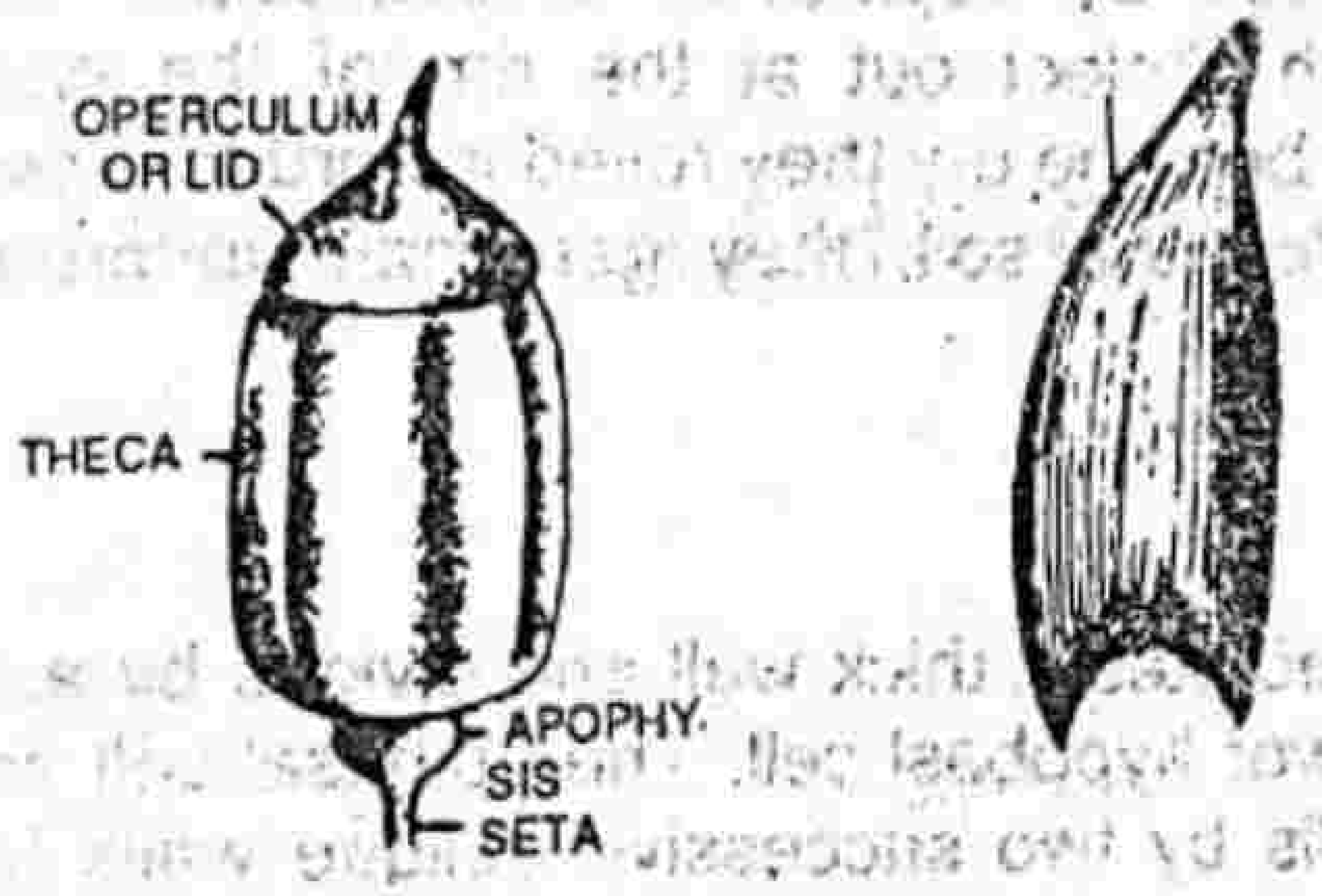
The spore sac on both outer and inner side, is bounded by two layers of thin walled cells. All the sporogenous cells get transformed into the spores.

Columella

The central part of capsule is sterile and forms the large columella. There are narrow spore sacs all around the columella. These spore sacs are filled with spores. The spores are produced after meiosis from the spore mother cells.

Calyptra

The cap present on the capsule is known as calyptra and represents the upper half of the sporangium.



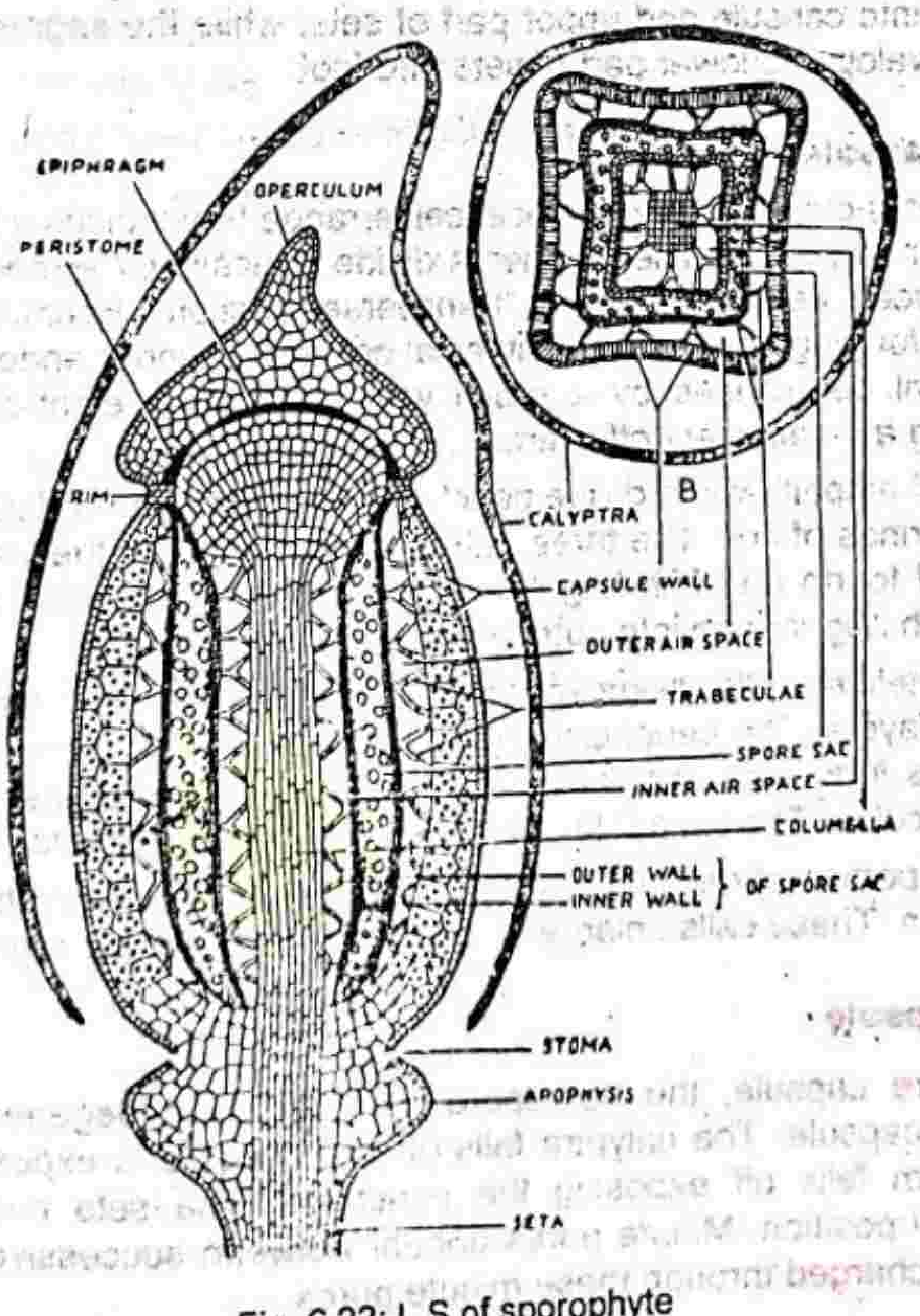


Fig. 6.22: L.S of sporophyte

Operculum

There is a circular lid, the operculum at the top of the capsule.

Peristome

There is a ring of elongated teeth below the operculum these teeth form the peristome. The teeth are 32-64 in number and attached with the wall of capsule. Teeth are hygroscopic and help in the gradual dispersal of spores.

Dispersal of spores

The spores are dispersed by separation of operculum from the top of the capsule. The peristomium teeth project out at the rim of the capsule under humid conditions. When the conditions became dry they rolled inward to prevent the dispersal of spores When the spores fall on the soil, they germinate to produce a filamentous structure called as protonema.

Development of Sporophyte

The zygote enlarges, secretes a thick wall and divides by a transverse wall into an upper epibasal cell and a lower hypobasl cell. The epibasal cell as well as hypobasal cell cut off two-sided apical cells by two successive oblique walls to establish growing points in opposite directions. The segments are cut off alternately from upper apical cell and these develop into capsule and upper part of seta, while the segments derived from lower apical cell develop into lower part of seta and foot.

Development of Capsule

(i) The segments cut off by upper apical cell arrange themselves into two alternating semicircular segments. The segments divide radically by a median vertical wall. These appear as quadrants in transverse section. Each quadrant divides periclinally forming an outer amphithecial cell and an inner endothecial cell. Each amphithecial cell divides by a radial wall to produce eight-cell amphithecium surrounding a 4-called endothelium.

(ii) The cells of amphithecium divide periclinally first and then radically to form seven concentric rings of cell. The three outer rings give rise to the wall of the capsule, the cells of fourth and fifth ring develop into outer trabeculae and cells of sixth and seventh ring mature into outer wall of the spore sac.

(iii) The endothelium cells divide repeatedly in all planes and arrange themselves into many layers. The peripheral layer gives rise to sporogenous tissue. The two inner layers form inner wall of the spore sac and cells of last layer mature into inner trabeculae. The central layers of cells produce columella.

(iv) The apical portion of capsule develops from the cells of amphithecium as well as endothelium. These cells enlarge and give rise to opercular region.

Dehiscence of Capsule

In a mature capsule, the non-spore forming tissue degenerates and spores accumulate in the capsule. The calyptra falls off and capsule is exposed and begins to dry. The operculum falls off exposing the peristome. The seta curves and capsule assumes horizontal position. Minute pores appear between successive peristome teeth. The spores are discharged through these minute pores.

Spore Structure and Germination

Each spore is uninucleate and surrounded by a two-layered wall. Upon reaching a suitable place for germination the spore absorbs water, its outer wall layer ruptures and it germinates into germ tube that produce branches to give rise to a filamentous protonema. Some of its branches are colourless, enter the substratum and act as rhizoids. Other branches are chlorophyllous and these spread on the surface of substratum. Several buds grow on a fully developed protonema. Each bud cuts off an apical cell with three cutting faces and develops into a leafy gametophore.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are bryopsida.
2. What are mosses.
3. Define alternations of generations in funaria.
4. Name two species of funaria.
5. Describe structure of antheridium of funaria.
6. What are hairy cap moss.
7. What is the structure of mature antheridium of polytrichum.
8. Draw plant body of polytrichum.
9. What is sporophyte.
10. Draw L.S. of sporophyte of funaria.

B. Long Questions

1. Describe asexual reproduction in funaria.
2. Describe sexual reproduction in funaria.
3. Describe sporophyte of funaria.
4. What is alternations of generations. Describe life cycle of funaria.
5. Describe structure and reproduction of gametophyte of polytrichum.
6. Describe sporophyte of polytrichum.
7. Describe sporophyte of funaria and compare it with sporophyte of polytrichum.

SECTION VIII

INTRODUCTION TO VASCULAR PLANTS

Chapter 7

INTRODUCTION TO VASCULAR PLANTS

It is generally agreed that life arose in an aquatic environment and then flourished during more than 3 billion years. The vascular plants, i. e., the plants having conducting tissues, the xylem and phloem, originated in late Silurian period (about 400 million years ago) and colonized the land. Considerable diversification of these plants occurred by late Devonian period (about 345 million years ago) and at least seven great lines of vascular plants are found in this era.

Organization of the Vascular Plant Body

Most vascular plants are composed of well differentiated vegetative and reproductive organs. The vegetative organs are stem, root, and leaf; and the reproductive organs include spore-bearing organs, the sporangia; seeds and fruits.

The Stem

An individual vascular plant usually originates from zygote which first develops into a mass of undifferentiated cells, that differentiate externally into leaves, stems and roots and internally into component tissues.

The Root

The stems of all vascular plants except a few ferns and fossil pteridophytes bear roots. Roots differ externally from stems in not bearing leaves and not differentiated into nodes and internodes.

The Leaf

The leaves arise at the surface of young stems. A mature leaf may be simple, if the leaf blade remains undivided; or compound, with leaf blade divided into leaflets.

Two categories of leaves are recognized in vascular plants.

i. **Microphylls:** These are usually of small size, have single unbranched veins and leaf traces are without leaf gaps. However, in certain fossil plants and Isoetes leaves of large size are found. Scale-like emergences present on the stems of certain fossil and living (*Psilotum*) pteridophytes are considered to be precursors of microphylls.

ii. **Megaphylls:** These are large in size, their veins are much branched and their leaf traces leave gaps in the stem stele. Megaphylls are considered to be modified stems that originated from the distal branches of the stem through evolution.

NATURE OF VASCULAR TISSUE

The vascular tissue comprises of xylem and phloem tissues.

Xylem

The xylem is water-conducting tissue of the vascular plants that differentiates from procambium. The first formed xylem is called protoxylem. Its elements are usually smaller in diameter and differentiate before the elongation of the stem stops. The later formed xylem is called metaxylem. It matures after the elongation of the stem has ceased. Its elements are larger in diameter, contain more secondary wall material and specialized structures, the pits in their walls.

The differentiation of xylem from procambium shows four common patterns or directions.

i. Exarach (Gr. beginning outside):

If the maturation of xylem elements occur in a centripetal order, such a xylem is called exarach. The initial mature xylem elements are located away from the centre of the axis. The exarch xylem is characteristics of roots of seed plants.

ii. Endarch (Gr. beginning within):

If differentiation of xylem elements starts near the centre of the axis, i. e., centrifugally, the xylem is termed endarch. The newly formed xylem elements are develop away from the centre of the axis. This type of xylem is usually found in stems of seed plants.

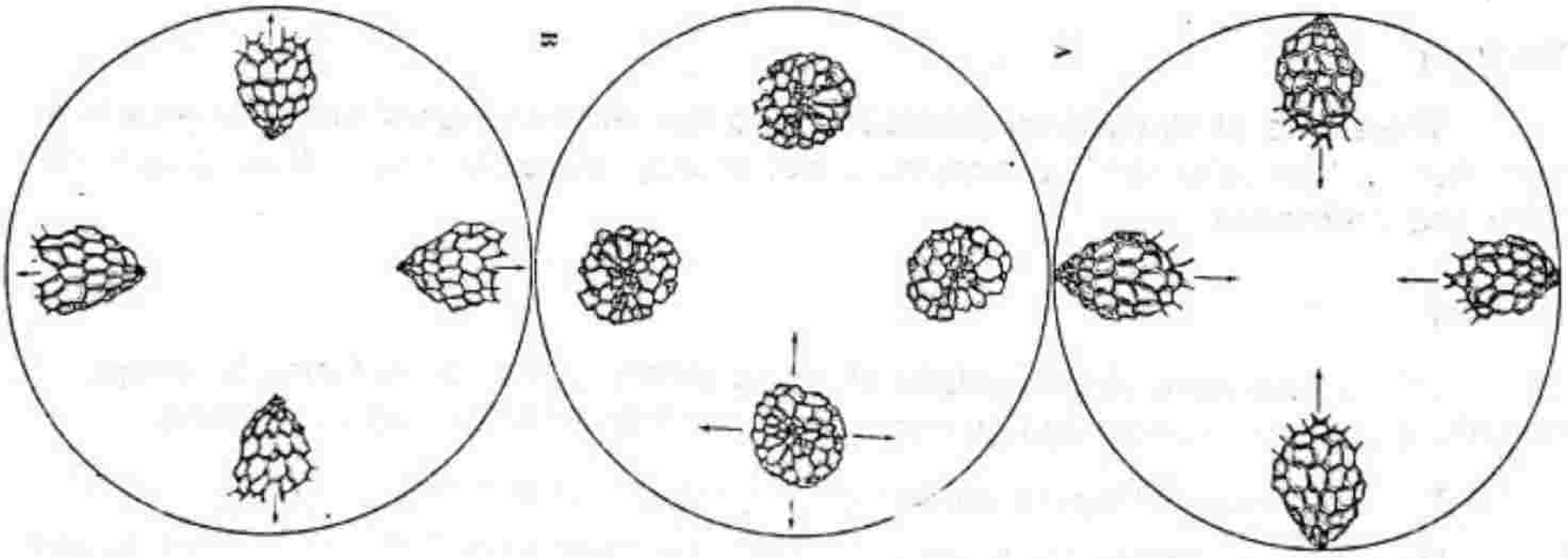


Fig. 7.1a: Differentiation of xylem — A. Exarach; B. Mesarch; C. Endarch.

iii. Mesarach (Gr. beginning within):

In this type, the differentiation progresses in two or more directions from the first mature xylem elements.

iv. Synchronous:

The xylem consisting of metaxylem only is called synchronous. It is found in the hypocotyl region of angiospermic seedlings.

Phloem

The primary phloem usually differentiates from procambium that are situated towards the outer part of the stem or root axis. The first formed phloem is called protophloem and its maturation is complete before the elongation of stem ceases. The phloem that matures from the procambium after the maturation of stem stops is called metaphloem. In pteridophytes and in gymnosperms sieve cells are the conducting cells of the phloem.

Stele

The xylem and phloem together form the stele (L. stela=rod or column). The procambium assumes different patterns in various plants, and when vascular tissue differentiates, different stelar configurations result. These stelar types are used in classification and relationship of vascular plants.

The usual types of steles recognized in vascular plants are: the protostele, the siphonostele, the eustele and the atactostele.

1.Protostele

When the procambium is in the form of a solid cylinder, the xylem surrounding the phloem, the stele is called protostele. It is considered to be the most primitive stele and was present in earliest vascular plants. Almost all roots are protostelic.

The protostele is further divided into:

i. **Haplostele,** when the xylem of the protostele is round in cross section.

ii. **Actinostele,**It is starch shaped and xylem cylinder has ridges and furrows and the phloem is situated within these furrows.

iii. **Plectostele,** when the phloem is dispersed among the xylem cells as patches.

2.Siphonostele

In a siphonostele, the xylem and phloem form a cylinder around a central pith. The siphonostele may be:

i. **Ectophloic siphonostele**, when the phloem is present on the outer surface of the xylem.

ii. **Amphiphloic siphonostele,** in which the phloem is both on the outside and inside of the xylem. It is also called a solenostele and usually found in ferns.

3.Eustele

When the xylem and phloem occur together in discrete bundles, it is called eustele. A eustelic bundle may be may be:

i. **Collateral,** in which the phloem is present outside the xylem).

ii. **Bicollateral,** when the is present phloem towards the outside as well as the inside of the xylem. The gaps between the bundles are not due to appearance of leaf traces. Eustele is found in Equisetum, most gymnosperms and dicotyledonous flowering plants.

4.Atactostele

An atactostele is composed of many vascular bundles present throughout the living tissue of a stem. Some authors regard is as a modified eustele. It is found in stems of monocotyledonous flowering plants.

5.Dictyostele

A siphonostele may not be complete because of interruptions by the leaf gaps. In siphonostelic stems with closely spaced leaves, leaf gaps overlap and only one leaf gap may be seen in a cross section. Presence of many leaf gaps in a siphonostele make it appear as dissected. Such a siphonostele is called a dictyostele and is found in many ferns.

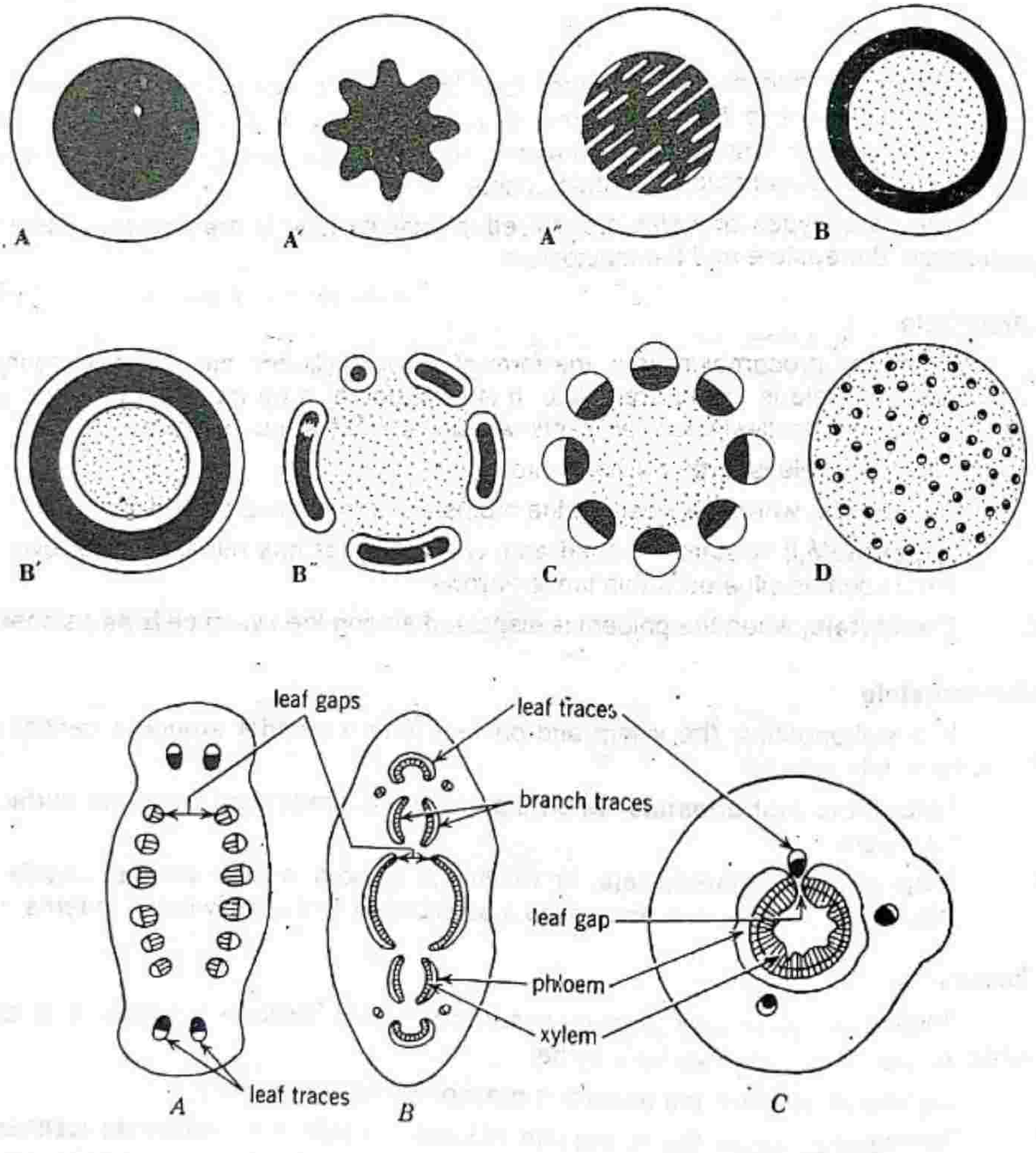


Fig. 7.1b: Types of stele — A-A". Protosteles: A. haplostele, A'. actinostele, A". plectostele; B. Ectophloic siphonostele, B'. Amphiphloic siphonostele, B". Dictyostele; C. Eustele; D. Atactostele; E. Leaf traces and leaf gaps.

Leaf Traces and Leaf Gaps

The branches of xylem and phloem to leaves are called leaf traces. The separation of leaf traces influences the configuration of the stele. In some plants the traces are single and composed of only a few xylem and phloem cells, and their separation from the stele do not disturb the vascular tissue of the stem. But in pteridophytes a large branch or several branches of vascular tissue pass out as leaf traces. These interrupt the vascular cylinder. These interruptions are called leaf gaps. These gaps become filled with parenchyma cells.

Evolutionary Relationship Among Steles

It has been suggested that siphonosteles developed by progressive replacement of xylem elements by parenchyma cells in the center of protosteles. This hypothesis is supported by the persistence of tracheids in the pith in some plants. The dissection of siphonostele to discrete vascular bundles by leaf traces and associated gaps in ferns suggest that this process resulted in evolution of eustele and atactostele. The opponents of this hypothesis are of the view that eustele arose by fragmentation of lobed protostele into discrete vascular bundles.

FOSSIL RECORD & GEOLOGICAL TIME SCALE

FOSSIL RECORD AND GEOLOGICAL TIME SCALE

*The remains of plants and animals, which lived in the remote past, are preserved in the rocks in one form or the other. These are called the **fossils**.*

A brief knowledge of the different types of fossils is essential to know the type of plants that lived in ages bygone and to form an idea of evolutionary process that has gone on for times immemorial and is still going on. A fossil in reality is a clear manifestation of the existence of prehistoric living beings.

Fossilization Process

There are some factors involved during the fossilization process. There can be listed as under:--

1. The nature of the plant or animal material e.g., whether it was a thin and delicate plant part or a tough and woody portion.
2. The kind of entombing material.
3. The rapidity with which the plants were covered and thus prevented from exposure to organisms of decay.
4. The condition of the plant material at the time of fossilization.

Types of Fossils

There is variety of forms of fossils depending upon the conditions under which fossilization occurred. Following are the different kinds of fossils

1. **Dead and Preserved Bodies:** The actual dead and preserved bodies of plants and animals or parts of bodies are preserved in rocks or ice. The original tissues remain intact in the fossilized material.
2. **Compressions;**Such fossils are formed when the whole plant or part of a plant gets buried under sediments of different types. Due to the weight of these sediments, the plant part becomes flattened resulting in the formation of a carbonaceous film. They reveal only the outlines and external features of the plant or plant part. A very little or no cellular detail is preserved in such fossils
3. **Impression or Imprints:** They are formed when the sediments around the compressed plant or plant part become hardened. They very clearly reveal the outline of the plant or its part. They are regarded as negatives of the compression. Such fossils only reveal the outline of a plant or its part. The cellular details are not preserved. In some cases the sediments all around the plant or plant part harden and form a three dimensional mold.
4. **Petrifactions:** They are considered to be the best type of fossils. They reveal the internal structure of the part which is petrified. The process of petrifaction consists in the molecule-by-molecule replacement of the plant part by minerals in solution that ultimately harden. It so happened that the entire forest or a group of plants growing in a locality got buried under the ash from nearby volcanoes.
5. **Encrustation Fossils:** Such fossils are neither compressions nor petrifactions. These fossils are usually found in hot springs whose waters contain abundant mineral matter. The fallen twigs, leaves, spores, algae and bacteria that live in such hot springs become coated with the carbonates and are encapsuled. These carbonates become precipitated on cooling. During encrustation decaying

organisms and air are excluded so that the organisms remain as such even for millions of years.

6. **Calcification:** This process is used by some algae. They secrete a heavy coat of calcium carbonate around them. This coat preserves them for millions of years and these calcified algae can be studied for their details. It is now believed that the "coral reefs" found in the oceans are built more by the secretion of calcium carbonate by marine algae rather than by the corals.

7. **Diatomaceous Earth:** Deposits of diatomaceous earth are found in many parts of the world. It is believed that such regions were earlier inundated by the oceans that were inhabited by countless members of tiny unicellular algal organisms called the diatoms. These algae were encapsuled by beautifully sculptured frustules or shells made of silica (secreted by these algae). After the death of these diatoms, their siliceous shells sank to the bottom of the sea. The mass of these shells went on accumulating at the bottom for millions of years and formed the diatomaceous earth.

8. **Actual Remains.** Such plant fossils are of comparatively young age and do not decompose completely due to low temperature or vacuum. All materials that are resistant to natural decomposition are preserved e.g., cuticle, cutin, sporopollinin in the walls of pollen grains and spores.

9. **Chemical Remains:** Chemical materials like amino acids and hydrocarbons may be obtained in a natural state or in a modified form from the rocks in which organic matter of the petrified plant part or organ has been incorporated.

GEOLOGICAL TIME SCALE

The sedimentation at a particular location is not continuous but occurs in intervals when sea level changes or lakes and swamps dry up and refill. As a result of different periods of sedimentation, the rock is formed in layers or strata. The younger sediments are superimposed upon older ones. The fossils preserved in each layer represent the time when the sediment was deposited. Thus, the sediments tell the relative age of the fossils. The strata at one location can be correlated with strata at another location by the presence of similar fossils.

By studying many different sites, the geologists have established a geological time scale. It is a time scale that reflects a consistent sequence of historical periods. It is grouped into four eras: Precambrian, Paleozoic, Mesozoic and Cenozoic. These eras in turn are sub-divided into periods. Each period is split into number of time intervals, the epochs.

Each era represents a distinct age in the history of earth's life. The boundaries are marked in the fossil record by explosive radiations of many new forms of life following mass extinctions. For example, the beginning of the Paleozoic era is recorded by a great diversity of fossilized invertebrates that are absent in the rocks of late Precambrian era. The boundaries between periods within each era also mark major transitions in the form of life fossilized in rocks.

The Palaeozoic and Mesozoic eras are very important from the study point of view of the fossil plants. The first land plants are found in upper middle Palaeozoic (lycopods, horsetails, seed ferns). In the late Palaeozoic (upper and lower Carboniferous) forests comprising of ferns, seed ferns and primitive gymnosperms appeared on earth.

GEOLOGICAL TIME SCALE

A geologic time scale with notes of events in the evolution of plants and environments.

ERA	PERIODS AND EPOCHS approximate time since beginning		PLANTS	CLIMATES
CENOZOIC	Quaternary	Recent Pleistocene 1,000,000 years ago	Dominance of herbs Increase of herbs Decrease of trees	Climatic zones and changes of season Periodic continental glaciers in north
	Tertiary	Pliocene 13,000,000 years ago	Rise of herbs Spread of grasslands	Cool and temperate climates away from equator
		Miocene 25,000,000 years ago	Development of grasses Reduction of forests	Cooling of climates
		Oligocene 36,000,000 years ago	Worldwide tropical forests	Warm climates still widely spread
		Eocene 58,000,000 years ago	Extension of angiosperms	Zoned climatic belts well established
		Palecene 63,000,000 years ago	Modernization of angiosperms	Development of climatic belts
MESOZOIC	Cretaceous	135,000,000 years ago	Rise of flowering plants Decrease of conifers	Birth of modern mountains Development of climatic diversity
	Jurassic	180,000,000 years ago	Conifers and cycads dominant First known flowering plants	Culmination of worldwide warm climates
	Triassic		Increase of conifers First known cycads	Worldwide tropical and subtropical climates

PALEOZOIC	Permian	230,000,000 years ago	Dwindling of ancient plants Seed turns extinct	Climates become varied Glaciation in southern hemisphere
	Carboniferous (Pennsylvanian)	280,000,000 years ago	Great tropical coal forests	Uniform climates throughout world
	Carboniferous (Mississippian)	310,000,000 years ago	First known mossess seed ferns, and conifers Early coal forests	Uniform climates Spread of tropical seed
	Devonian	345,000,000 years ago	First forests First known liverworts horsetails, and ferns	Broad distribution of uniform climates Increased temperatures
	Silurian	405,000,000 years ago	First known land plants and club– mosses	Slight climatic cooling
	Ordovician	425,000,000 years ago	Marine algae dominant	Warm climates
	Cambrian	500,000,000 years ago	Algae, fungi and bacteria First plant spores	Climates become progressively warmer
PRE-CAMBRIAN		600,000,000 years ago	Bacteria, fungi and algae	Cool climates at end of Pre-Cambrian Glaciation
		5,000,000,000 years ago		

The Mesozoic era is important with respect to appearance of flowering plants. The gymnosperms disappeared in the late Mesozoic.

Plant Life on Earth Time Scale

Fossil evidence of first photosynthetic organisms comes from a period of the earth's history called the Precambrian. This period covers about nine-tenth of the total age of the each, starting with earth's beginning and continuing up to the time of the Cambrian period. Since the Cambrian period started, about 600 million years ago, all the evolution of land organisms has occurred.

During the Precambrian period, tremendous reefs of limestone($CaCO_3$) were formed. These limestone deposits have been compared with similar limestone formation produced by present-day blue-green algae. However, the remains of algal cells are not found in these ancient limestone deposits. In 1954, the first fossilized remains of organisms was reported in a very hard rock called chert of Precambrian age, about 1.6 billion years old. The organism was found similar to fungal hyphae and spores, and the colonies of the cells were much like modern blue-green algae. The discovery confirmed blue-green algae as one of the earliest cellular organisms of the earth. Further accumulation of evidence from Precambrian fossils suggests that organisms of the Precambrian period were very primitive in structure and they lived in water.

The main fossil record begins in Cambrian rocks about 600 million years old. At the beginning of Paleozoic era, the life was confined to the sea. The plants were simple. Near the end of Cambrian period, by the time of Silurian period, the green plants invaded land. The green land plants evolved in two principal directions. One group remained small and developed the ability to colonize almost-bare rock surface. This first group gave rise to the mosses and liverworts. The second group evolved an ever-increasing amount of conducting and supporting tissue, and true leaves. These plant lines evolved into the ferns and all other higher plants, the trees, shrubs, and herbaceous flowering plants.

Land plants were not very common in the Silurian, or even early in the Devonian. By the end of Devonian, there were forests. The plants in these forests were giant species of club-mosses, horsetails and tree-ferns. These land plants developed luxuriously during Carboniferous (380 to 245 million years ago). This the time when coal deposits were formed. Coal beds are fossilized remnants of plants that grew in swamps. The climate was largely tropical and sub-tropical in those days.

By the end of the Paleozoic, the environment began to change. Some warm parts of the world became increasingly cold. The land masses emerged and great mountain chains were pushed upward. The Permian period saw the increased variety of environment. There were hills and lowlands, swamps and deserts, and varied climates. The earlier forests of club-mosses, horsetails, and ferns are overshadowed by forests of cycads, ginkgos and conifers. Representatives of these groups are still living as pines, firs, and spruce.

The last part of the Mesozoic and the first part of Cenozoic were periods of mountain-making. All the great mountain systems of the present like Himalayas were formed. The uplift of these huge mountain chains greatly affected the environment and evolution of Cenozoic plants. The earliest flowering plants (angiosperms) appeared late in Mesozoic. They probably lived in mountainous regions, while the conifers and cycad-like plants dominated in plains. The environmental changes that gave the flowering plants their first advantage over gymnosperms was cross-fertilization, seed dispersal and establishment of seedlings by insects and birds. About 70 millions years ago, the plants were essentially like those of modern times.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are vascular plants.
2 What are microphylls and megaphylls.
3. Define stele.
4. What is protostele. Give its types.
5. What is siphonostele. Give its types.
6 What is eustele.
7. What is protoxylem.
8. What is exarch xylem.
9. What are fossils.
10. What is geological time scale.
11. What is fossilization process.
12. Name different types of fossils.
13. What is petrificatgion.
14. What is era in time scale.
15. What is Mesozoic era.

B. Long Questions

1. What is stele. Give its types.
2. What are fossils. Write note on time of fossils.
3. Write note on geological time scale.

PTERIDOPHYTA

PTERIDOPHYTES

Vascular cryptogams are, an assemblage of seedless vascular plants that have successfully invaded the land and reproduce by means of spores.

Pteridophytes (Gr. pteron=feather, refers to feather-like pinnate fronds) have certain characters not found either in bryophytes or in seed plants. They differ from them in having both the gametophytes and sporophyte independent plants at maturity. On the basis of vegetative structure of the sporophyte, the manner sporangia are borne and the structure of the sporangia, the pteridophytes can commonly be differentiated as psilophytes, lycopods, horsetails and ferns.

The pteriodphytes have a long fossil history and can be traced back to the Silurian (about 400 million years ago). They flourished well from Devonian to Pensylvanian periods of the late Paleozoic which is usually regarded as the age of pteridophytes. Tree ferns, giant horsetails and arbo lycopods dominated the landscape during this era. The plant bodies of earliest known pteridophytes were rootless and leafless (in certain cases small leaves without veins were present on the branches). The sporangia were borne singly at the tips of branches. The sporangia resemble those of bryophytes. These are commonly termed as psilophytes.

Psilotum and Tmesipteris are two living pteridophytes which have retained these old primitive characteristics. The present day lycopods (Lycopodium, Isoetes, Selaginella) and sphenopsids (Equisetum) are true copies of their ancient ancestors that reached 120 feet in some cases (Lepidodendron, Calamites).

GENERAL ACCOUNT OF PTERIDOPHYTES

Habitat

The pteridophytes grow in a variety of habitats. Most pteridophytes are terrestrial plants and grow well in abundant moisture and shade while some flourish in open, dry, xeric conditions. A few are aquatic while still others are epiphytic.

The Plant Body

The dominant phase is a sporophyte. It consists of a shoot system made up of stems, leaves and roots. Some primitive pteridophytes were rootless, leafless and free-living sporophytes. These consisted of a dichotomously branched axis (psilophytes __ Rhynia) bearing rhizoids on the underground part of the axis which acted as absorbing structures. The modern survivors of psilophytes *Psilotum* and *Tmesipteris* are also rootless. The roots originated during later phases of growth.

The Stem

The shoots are characterized by presence of apical meristems at their tips which are responsible for branching and organ formation.

The shoots exhibit two types of branching:

i. **Dichotomous Branching:** The root or shoot apex divides into two sister apices, each developing into a branch of equal size, for example in *Psilotum*.

ii. **Monopodial Branching:**In this type, the branches develop laterally some distance behind the main shoot apex from axillary buds. It is dominant type of branching in seed plants and found in few vascular cryptogams.

The Leaf

The most primitive fossil pteridophyte Rhynia was leafles. The axis of living genus Psilotum also bear small appendages without vascular supply. In *Lycopodium* and *Selaginella* these appendages are small but leaf-like, but in Isoetes the appendages have attained a considerable length.

Two morphologically different types of leaves are found in pteridophytes. These are:

i. **Microphyll:**It is a small leaf with simple vascular system. A single leaf trace diverges from the edge of the stele and extends as an unbranched midvein from the base to the apex of the leaf. The microphylls occur in all lycopods and Equisetum.

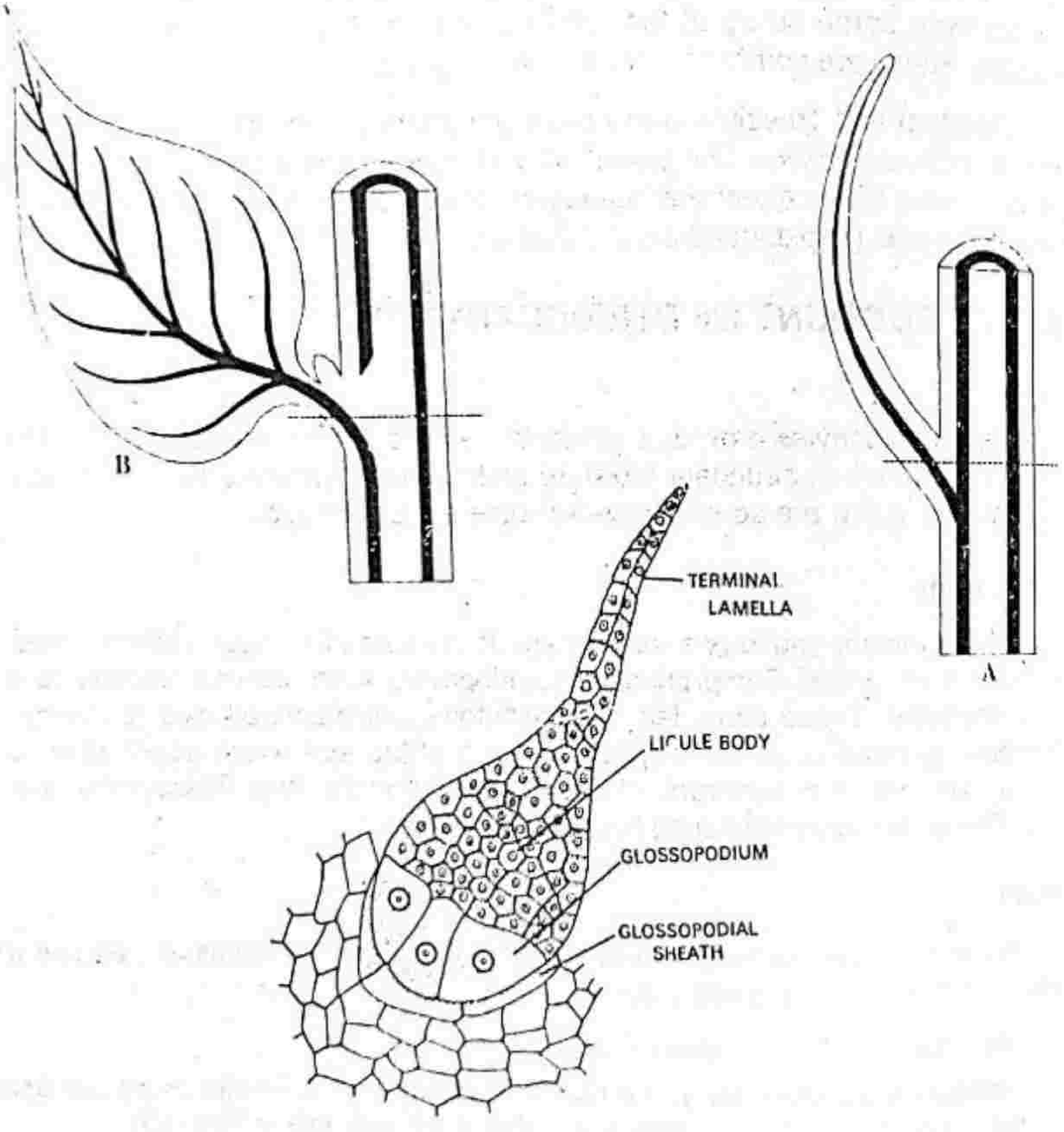


Fig. 7.2: A. Microphyllous and megaphyllous leaves; B. Ligule;

ii. **Megaphyll:**It is large leaf characterized by presence of two or more veins. The leaf traces are accompanied with leaf gaps. The venation is open dichotomous (the veinlets are dichotomously branched and terminate freely). The megaphylls are characteristic leaves of ferns.

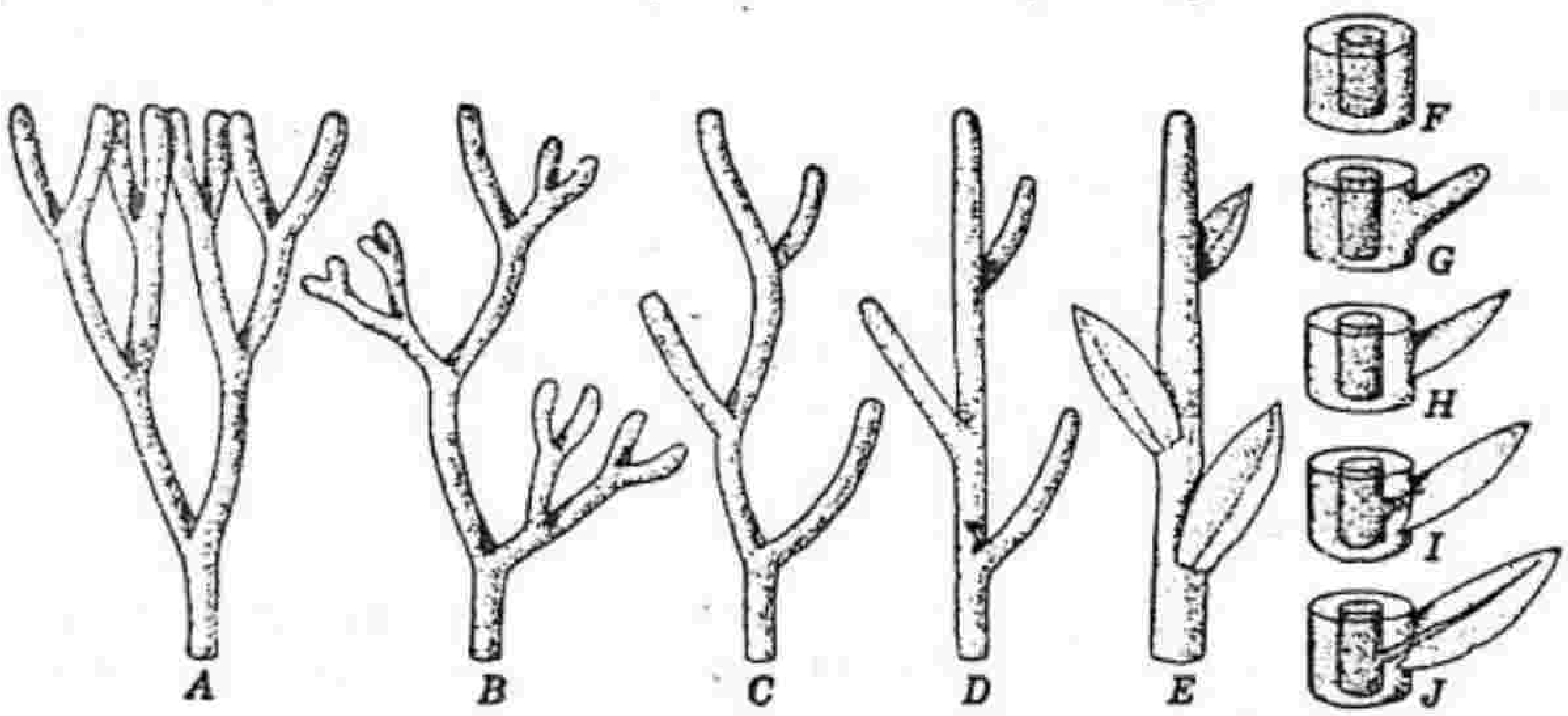
Ligule

In certain genera of lycopsids, for example Selaginella and Isoetes small scale-like outgrowth called ligule is present near the adaxial base of each microphyll.The ligule is considered to be a secretory organ which exudes water and mucilage that protect the young leaves and sporangia from desiccation. Transfusion tissue consisting of tracheid-like cells is present between ligule sheath and the adjacent vein of the microphyll.

On the basis of presence or absence of ligule, the lycopsids are arranged into two series: the ligulates, in which the ligule is present; and eligulates in which ligules are absent.

Origin of Leaf

According to Bower the microphylls originated as enations or superficial lateral outgrowths from the naked axes as in Psilophyton in which the enation was a small scale or spine-like outgrowth without leaf trace. In Asteroxylon the enation was provided with a rudimentary leaf trace which terminated at the base of the appendage. Additional support of enation theory of the microphyll is found in the shoots of Psilotum and Tmesipteris where the young axis is naked and the appendages are without vein in Psilotum whereas a single mid-vein is present in Tmesipteris. This theory of origin of leaf is called enation theory.



·. Diagrams showing origin of microphyllous leaves. *A–E*, according to the telome theory. *F–J*, according to the enation theory.

Fig. 7.3: Enation concept of origin of leaf.

On the other hand, Zimmermann (1954) was of the view that microphylls and scale-like appendages arose as a result of reduction from lateral dichotomously branched system of axes or telomes. This theory of origin of leaves is called telome theory. This theory is less widely accepted as for as the origin of microphyll is concerned, however it is widely accepted regarding the origin of megaphylls of ferns.

According to Zimmermann the development of a megaphyll took place by three successive phenomena namely overtopping, planation and webbing.

i. **Overtopping:**Beginning with a leafless and dichotomously branched plant such as Rhynia, unequal dichotomous branches resulted in the overtopping of the weaker branch by its more aggressive sister branch; this process was repeated at each point of a major dichotomy and resulted in the initial distinction between the axis and leaves.

ii. **Planation:** The lateral branches at first branched dichotomously in more than one plane but later restricted themselves to a single plane. This is planation.

iii. **Webbing:** The final step consisted in the fusion or webbing of the separate telomes of an overtopped lateral branch into a flat, primitive lamina characterized by presence of a simple open dichotomous venation. Later the fusions between the veinlets produced reticulate venation.

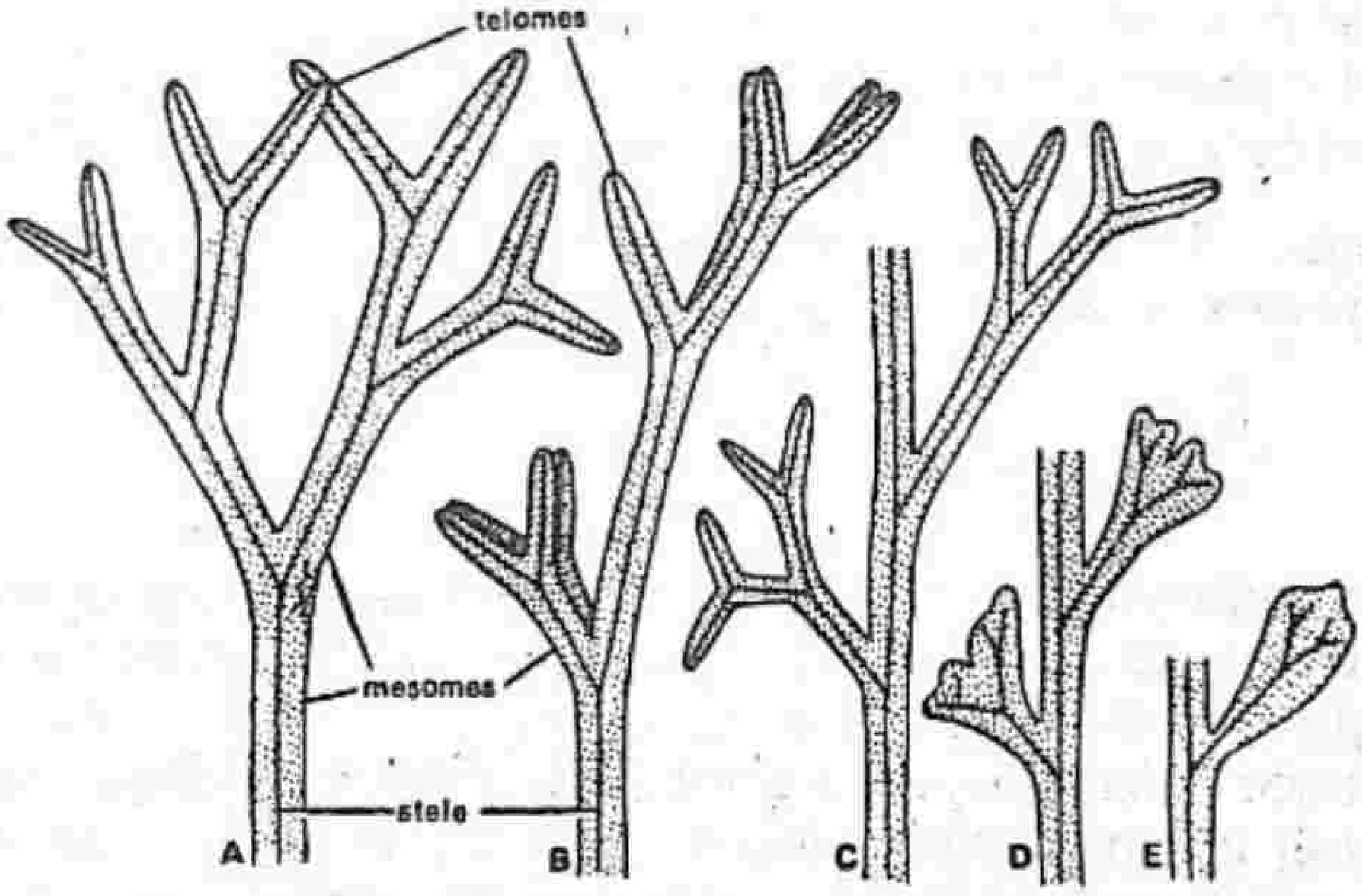


Fig. 7.4: Zimmermann's concept of origin of leaf.

Root System

The roots of most of the pteridophyte groups are adventitious structures and only in Isoetes a definite root system is present. The basal part of the axis bear roots. It has been observed anatomically that these are not true roots rather rhizomorphs. In Selginella the rhizomorphs are present but these are lateral structures and do not have indeterminate growth.

Vascular Tissue System

The sporophyte of pteridophytes is characterized by the evolution of two general types of conducting tissue, the xylem and phloem, not found in the cryptogams, i. e., algae and bryophytes. The origin of vascular tissue is unknown, however it is believed to be evolved from columella of Anthoceros sporophyte. The vascular tissue is present in the form of vascular bundles, a bundle comprising of xylem and phloem tissues. The vascular elements develop from a core of or column of meristematic tissue called vascular cambium.

Reproduction

The sporophyte reproduces by formation of spores, therefore the mode of reproduction is asexual.

Asexual Reproduction

The asexual reproductive units, the spores are produced in sporangia.

Sporangia

The sporangia differ in position, form, size, structure and method of development in different groups of pteridophytes. This characteristics is used for classification of vascular cryptogams.

The sporangia originated from stem and this fact is supported by position of sporangia in fossil pteridophytes Horneophyton and Rhynia and living pteridophytes Psilotum, Tmesipteris and Equisetum. In Equisetum the sporangia occur in circular groups attached to the under surface of peltate sporangiophore. A sporangiophore is regarded as highly modified fertile branch. In ferns the sporangia are related to leaves. A leaf or leaf-like structure which bears one or more sporangia is called a sporophyll. In Selaginella and most Lycopodium spp the sporophylls aggregate into a compact cone-like structure called strobilus.

Heterospory

The presence of morphologically and physiologically different types of spores is usually referred to as heterospory. Heterospory is found in almost all groups of pteridophytes, however it is not pronounced among giant horsetails but in lycopods (Selaginella) and ferns (Marselia) it is conspicuous and megaspores are many times larger than the microspores.

Sexual Reproduction

The spores on germination give rise to haploid monoecious or dioecious gametophytes. The gametophytes reproduce sexually.

Gametophyte

The sex organs develop on separate, independent but much reduced plants, the gametophytes. The gametophytes in vascular cryptogams are extremely reduced, photosynthetic and simple in structure. These are generally called prothalli (sing. prothallus).

The gametophytes may be:

i. **Exosporic,** when these are free-living and not enclosed by the spore wall. Exosporic type of gametophytes represent original and primitive condition. Exosporic gametophytes are monoecious, i. e., they produce both types of sex organs.

ii. **Endosporic**, when entire or most part of the gametophyte is enclosed in spore wall. Endosporic gametophytes are present in heterosporous species usually. Endosporic gametophytes are strictly dioecious.

Sex Organs

The sexual reproduction is by pairing of morphologically different gametes. The male gametes are motile, flagellated and usually termed male sperms, whereas the female gametes are passive and non-motile called the eggs. The gametes are produced in separate sex organs, the gametangia:

i. Antheridium:

The male gametangium commonly known as antheridium produces male sperms. The number of sperms vary from species to species. Each antheridium consists of a jacket of sterile cells enclosing the spermatocytes. The sperms are biflagellate, however in Isoetes multiflagellate sperms are present.

ii. Archegonium:

The female gametangium is archegonium. A typical mature archegonium consists of a neck which project above the surface of the gametophyte, and basal sunken portion, the venter. The neck contains an axial row of cells, the neck canal cells and the venter contains an egg and a ventral canal cell. The venter is surrounded by a sterile layer of cells forming jacket. The neck usually comprise of four vertically arranged rows of cells.

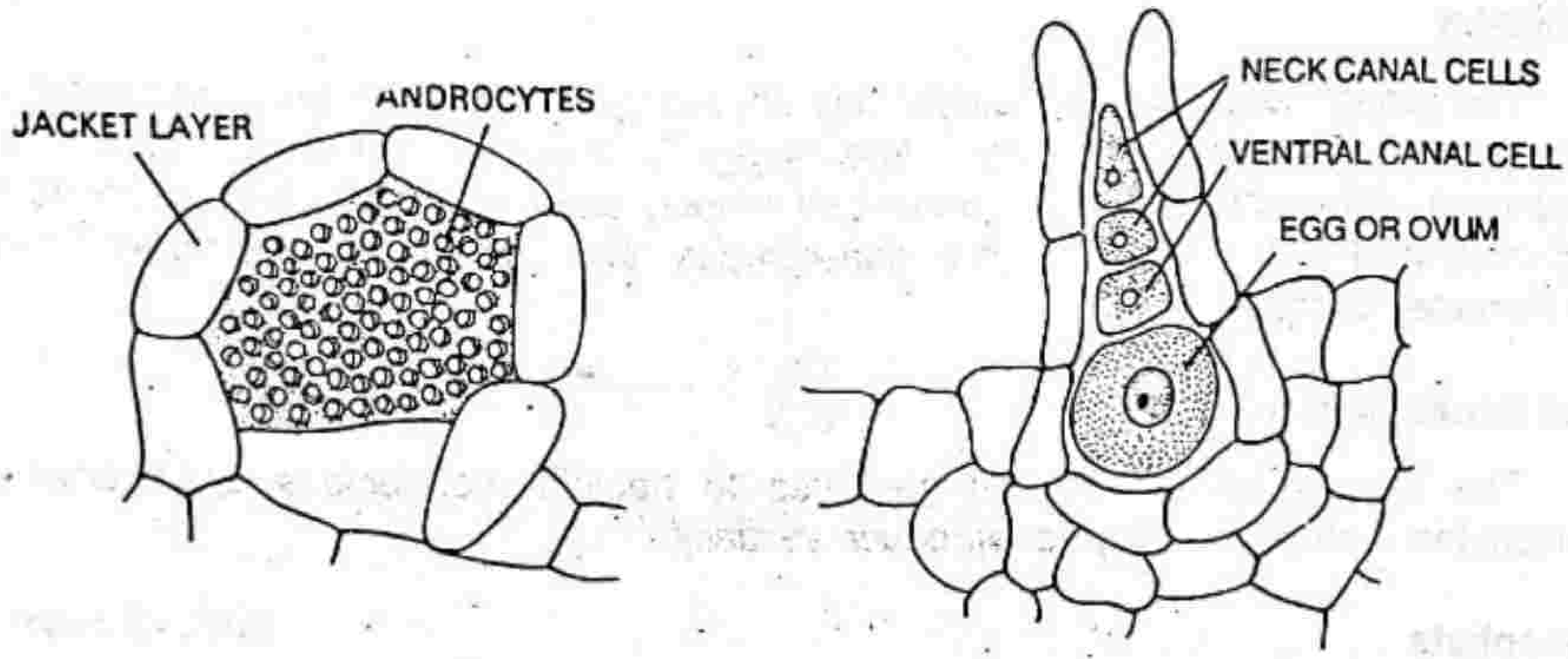


Fig. 7.5: Sex organs in pteridophytes.

Apospory

A gametophyte may develop by apospory from leaf of sporophyte along the margins or apex of the blade or from a sporangia in a sorus. Such gametophyte is commonly termed as aposporous gametophyte.

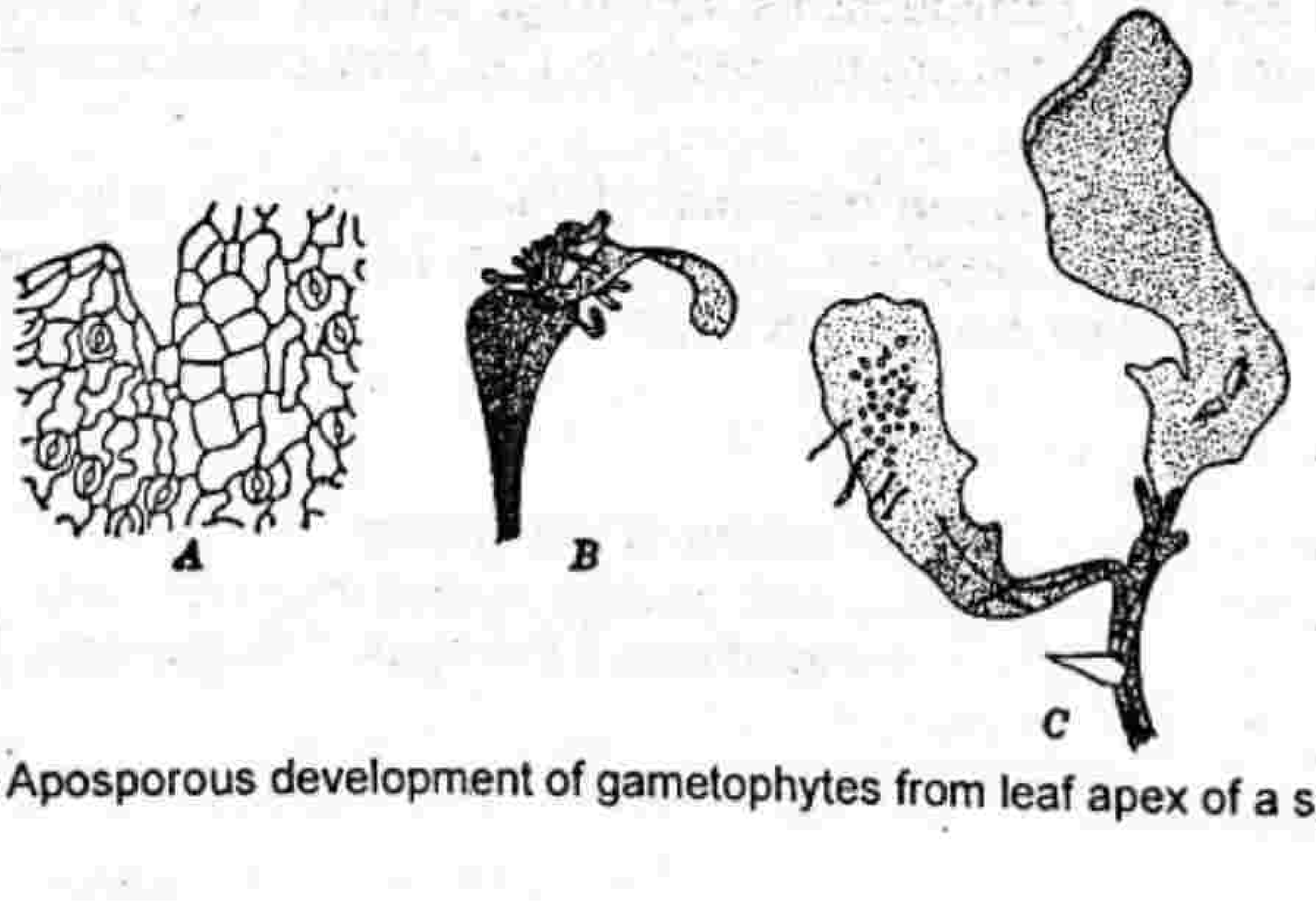


Fig. 7.6: Aposporous development of gametophytes from leaf apex of a sporophyte.

Apogamy

A sporophyte resulting from apogamy, called apogamous sporophyte, may develop from a single vegetative cell of the gametophyte or from the cell of an archegonium. In some cases, e. g., in Marselia the apogamous sporophyte may develop from the egg. Such a development of sporophyte is called parthenogenesis.

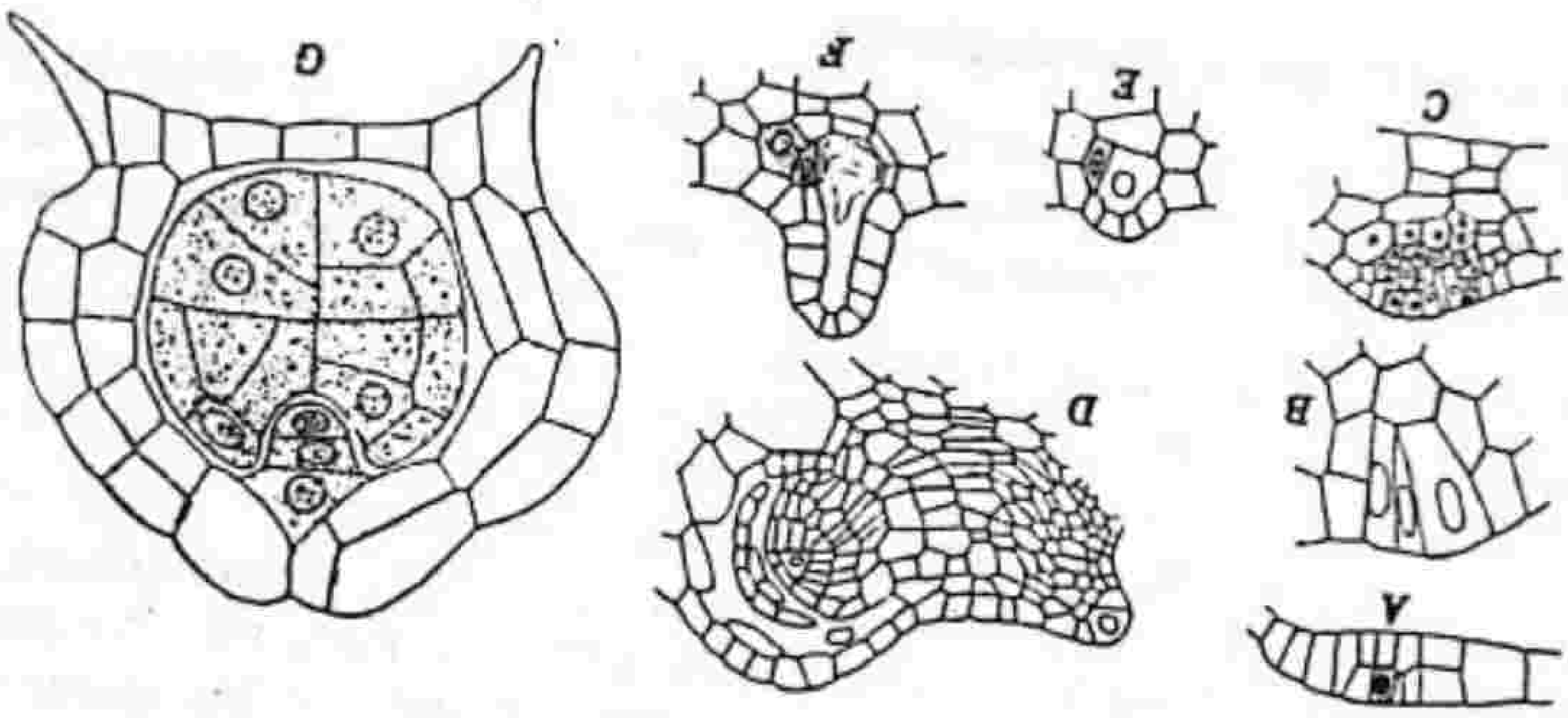


Fig. 7.7: Apogamous production of sporophytes.

Origin of Pteridophytes

There are two main theories regarding the origin of pteridophytes: one suggesting their origin from algae and the other from bryophytes. These theories are based upon comparative morphology of living and fossil forms.

Origin from Algae

The proponents of algal origin of pteridophytes consider that similarities between pteridophytes and bryophytes are because of parallel evolution and not because of phylogenetic connection between the two. Arnold and Church consider that pteridophytes have evolved from brown algae (Phaeophyta) which grew near the upper limits of the tide levels and migrated to land. Church suggested the origin of pteridophytes from green algae. There are two views regarding this origin. According to Bohlin, Fritsch, Lotsy the pteridophytes evolved from a chaetophoraceous alga. However, Fritsch (1945) is of the view that pteridophytes came from an erect parenchymatous alga that exhibited isomorphic alternation of generations.

Origin from Bryophytes

The bryophytes and pteridophytes are alike in so many features that there is good reason for thinking that there is a phylogenetic relationship between the two. These common features include:

i. Both exhibit terrestrial habit.
ii. The gametophytes in both are thallose.
iii. The sex organs, antheridia and archegonia exhibit similarity in development and structure.
iv. The development of embryo within the wall of venter.
v. Partial parasitism of mature sporophyte upon gametophyte. In pteridophytes the embryo is dependent upon gametophyte during earlier stages of development
vi. The heteromorphic alternation of generations.

There are two schools of thought regarding origin of pteridophytes from bryophytes. According to one, the two are divergent evolutionary lines evolved from hypothetical primitive archegoniate type land plants. The other school of thought advocates the origin from true bryophytes like Anthoceros. It is called anthocertotean origin.

Anthocertotean Origin of Pteridophytes

The theory was put forward by Campbell (1895). According to this theory the pteridophytes originated from Anthocerotae. The sporophyte, sex organs and embryos of anthocerotes have much common with their corresponding structures in pteridophytes.

Evolution of Sporophyte: It has been suggested that if meristem present at the base of anthocerotanean sporophyte is shifted to the apex, this would make possible an initiation of dichotomous branching by the meristem and restriction of spore formation to branch apices. The columella might metamorphose into a central conducting strand. Such a plant would resemble very closely the sporophyte of certain Psilophytales. Sporophytes have been found in which there is a restriction of spore formation to the distal end and in which the columella was differentiated into a conducting tissue in the lower portion.

The opponents of the theory were of the view that there is a wide gap between the anthocerotean type of sporophyte and root-bearing, free-living sporophytes of pteridophytes. However, the discovery of Psilophytales in which the plant body is a rootless, leafless, dichotomously branched axis invalidates this objection.

i. Evolution of Sex Organs:

In both bryophytes and pteridophytes, the sex organs are embedded in the gametophyte. In anthocerotes, the archegonial initial functions as primary archegonial cell which divides to produce an axial cell and three jacket initials. The archegonia are reduced and consist of jacket, cover cell and an axial row of cells. The pteridophyte archegonium developed by further reduction. The archegonial initial functions as axial cell directly and does not form jacket initials. Thus, the pteridophyte archegonium is homologous to axial row and cover cell of anthocerotean archegonium.

In anthocerotes, the antheridium develops in a cavity, the antheridial chamber. A superficial cell of the gametophyte divides periclinally into two daughter cells, the inner daughter cell developing into an antheridium, the outer developing into roof of the antheridial chamber. In primitive pteridophyes (Lycopodium, Equisetum, eusporangiate ferns), the antheridium consists of many fertile cells surrounded by a layer of sterile cells. The fertile portion of pteridophyte antheridium is considered to correspond to entire anthocerotean antheridium and sterile layer is homologous to the cover of the archegonial chamber.

ii. Evolution of Embryo:

The embryos of living Psilotales show a remarkable superficial resemblance to those of anthocerotes.

CLASSIFICATION OF PTERIDOPHYTES

AN OUTLINE OF CLASSIFICATION BY B. C. BOLD

Bold has classified pteridophytes into four divisions:

1.Microphyllophyta

The division includes club- and spike-mosses called so because of their moss-like size and leaves. The sporophylls of certain species are aggregated to form terminal groups or spikes. The division is divided into two classes on the basis of presence or absence of ligule: Aglossopsida (Lycopodium) and Glossopsida (Selaginella).

2.Arthrophyta

The division includes vascular cryptogams known from Devonian period. The plants were abundant during Paleozoic, but only a single genus, Equisetum is found in our present flora.

3.Pteridophyta

The division includes ferns. The members are megaphyllous. The division is divided into two series on the basis of type of sporangium produced: the eusporangiates, in which the sporangia contain a large number of spore, and leptosporangiates in which the sporangia contain a definite number of spores. The living ferns are grouped into five orders namely: Ophioglossales (Ophioglossum), Marattiales (Marattia), Filicales, Marsileales (Marselia) and Salviniales (Salvinia).

4.Psilophyta

The division includes two living genera Psilotum and Tmesipteris and extinct genera like Psilophyton, Rhynia, and Asteroxylon. The plants consist of dichotomously branched axes that arise from rootless rhizomes. The sporangia are united to form synangia and are borne on short lateral branches. The gametophytes are cylindrical, underground and saprophytic. The division includes a single order: Psilotales.

PSILOPHYTA*(PSILOPSIDA)*

The division includes both living as well as extinct genera. The living genera share most of their characteristics with extinct Psilophytopsida.

GENERAL ACCOUNT

1. The extinct genera are reported from Lower and Middle Devonian eras.
2. The living members are found in tropical and sub-tropical regions of both eastern and western hemispheres.
3. The members of division exhibit simple organization. The plants are rootless sporophytes in which the plant body is generally differentiated into a rhizoid-bearing underground portion, the rhizome, and an aerial portion.
4. The aerial portion is dichotomously branched (*Rhynia, Psilotum*). In most genera the aerial branches are leafless, but in few (*Psiltoum*) small, simple, veinless leaves are present.
5. The stele is protostele. ✓ (A O G)
6. The members of the division exhibit alternation of generations. The dominant phase is sporophyte. The gametophyte is independent but reduced.
7. The sporophyte reproduces by formation of spores. The spores are produced in thick-walled sporangia. The sporangia may be present singly at the tips of erect branches (Rhynia), or in groups of three's (synangia) at the upon the stem or at the bases of leaves (Psilotum). The plants are homosporous.
8. The sexual reproduction is by formation of gametes produced in definite sex organs, the antheridia and archegonia, on separate plants, the gametophytes.
9. The gametophytes are cylindrical, subterranean and saprotrophic. The antheridia lie partially embedded in the gametophyte. The sperms are multiflagellate.

PSILOTUM

Taxonomic Position

Division:	Psilophyta
Class:	Psilotopsida
Order:	Psilotales
Family:	*Psilotaceae*
Genus:	*Psilotum*

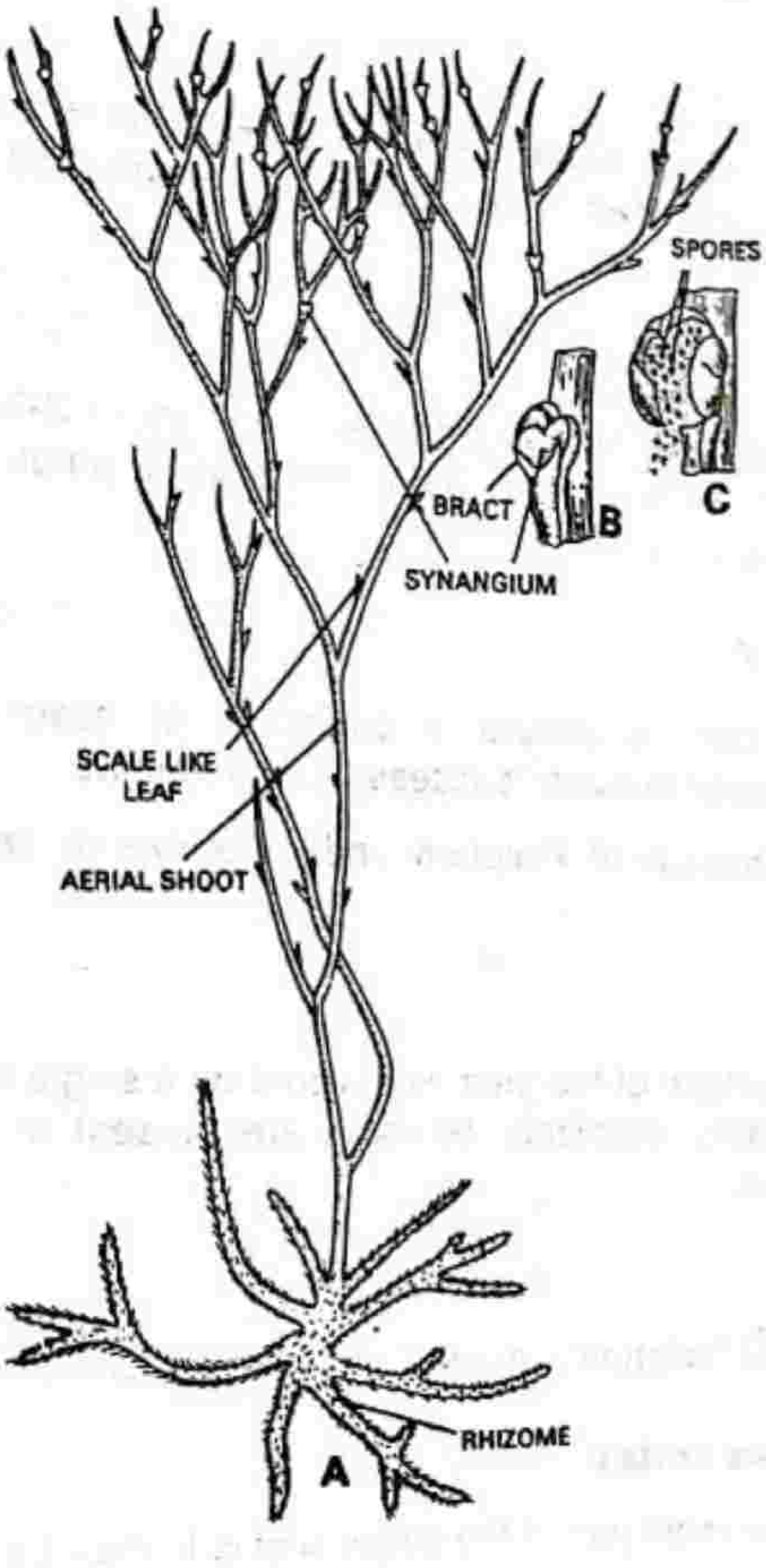


Fig. 7.8: A plant.

Occurrence

Psilotum, commonly called whisk fern, is found in humus-rich soil in tropical and sub-tropical regions. Some species grow as epiphytes, i. e., on the trunks of other trees.

Vegetative Morphology

Plant Body

The plant body is sporophyte and is differentiated into following parts

Rhizome

The horizontal portion is rhizome. It grows buried in the soil or humus. It is dichotomously branched. Two celled rhizoids are present near the apices of younger portion. The rhizoids absorb water and nutrients for the aerial portion of the plant.

Aerial Branch

The rhizome bears aerial branches. The aerial branches are green, cylindrical and dichotomously branched. The leaves are small and scale like are irregularly scattered over these branches.

Sporangia

The sporangia are homosporous and are about 2-3 nm in diameter. They are found in groups of three on short stalk in the axial of small bifid leaves. This group of sporangia is called as synangium.

STEM ANATOMY

The aerial stem is circular in outline at its base, pentagonal near the first dichotomy and triangular between successive dichotomies.

The aerial branch of Psilotum under transverse section shows the following demarcations.

Epidermis

The outer surface of the stem is covered by a single layer of epidermis. The wall of epidermis is heavily cutinized. Stomata are present in the epidermis, which are situated at the groves.

Cortex

The cortex of Psilotum is divided into following parts

1. Chlorenchmatous cortex

It is the outer most part of the cortex and is formed by 2-5 layer of cells. The cells are thin walled and are parenchymatous. The cells contained chloroplast so they are photosynthetic in nature.

2. Sclerenchymatous cortex

Below the parenchymatous cells there are 2-4 layers of sclerenchymatous cells. The cells are thick walled and they are sportive in function.

3. Parenchymatous cortex

They form the major portion of the stem. The cells are thin walled and having no inter cellular spaces in them.

Steler System

The stele of *Psilotum* consists of following parts, while pericycle and pith are usually absent.

Endodermis

There is well developed endodermis between the stele and the cortex. These cells has casparian bands on their radial wall.

Xylem

The xylem is actinostelic and radial in out line having six rays. The protoxylem elements are located at the tips of the rays. In the center the xylem core is present and form the metaxylem. The cells of xylem are thick walled and their main function is the transport of nutrients from lower part of the plant to the upper part of plant.

Phloem

Between the endodermis and the xylem is the phloem. The phloem is formed of thin walled cells. The phloem consists of sieve cells with sieve areas in their oblique end walls. Their nuclei disintegrate at maturity.

In case of rhizome, the epidermis is inconspicuous and all the cells of outermost layer of cortex extend into rhizoids. The cortex is thin walled and most of the cells contain fungus. The endodermis is conspicuous.The stele in rhizome is protostele. The pith is absent and xylem occupies centre of the axis and is surrounded by phloem.

Leaf Morphology and Anatomy

The leaves are scale-like appendages irregularly distributed on the aerial stem and are called prophylls. These are without vascular tissue and are made up entirely of photosynthetic parenchyma cells covered by an epidermis. In *Psilotum flaccidum* a leaf trace ends at the base of the prophyll. The stomata are absent.

Reproduction

The life cycle in *Psilotum* is characterized by alternation of generations. Both the spore- and gamete-producing generations are independent.

The Sporophyte — Asexual Reproduction

The sporophyte reproduces by formation of asexual reproductive units, the spores, produced in complex trilobed structures, the synangia.

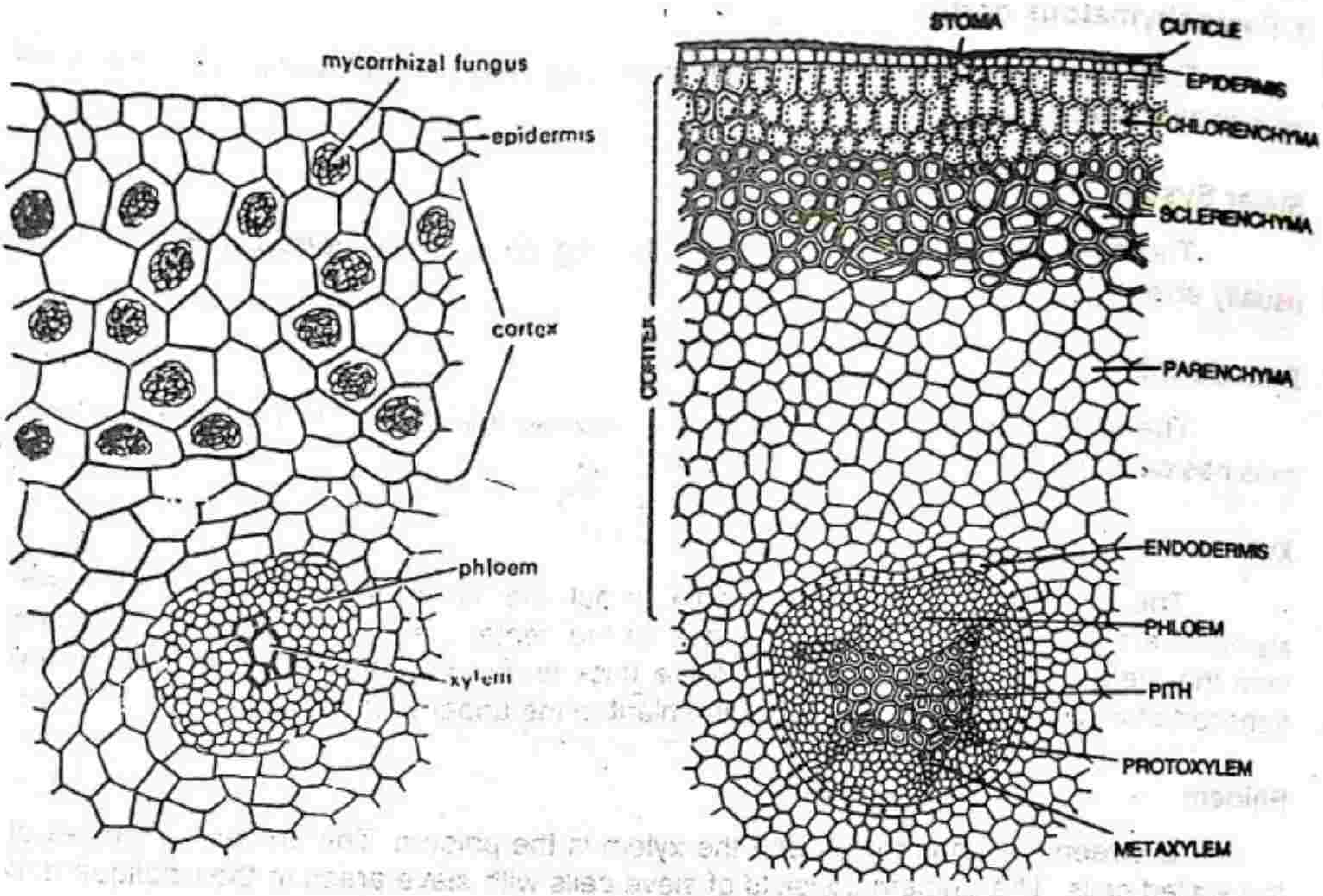


Fig. 7.9: Psilotum — Internal structure of aerial stem and rhizome.

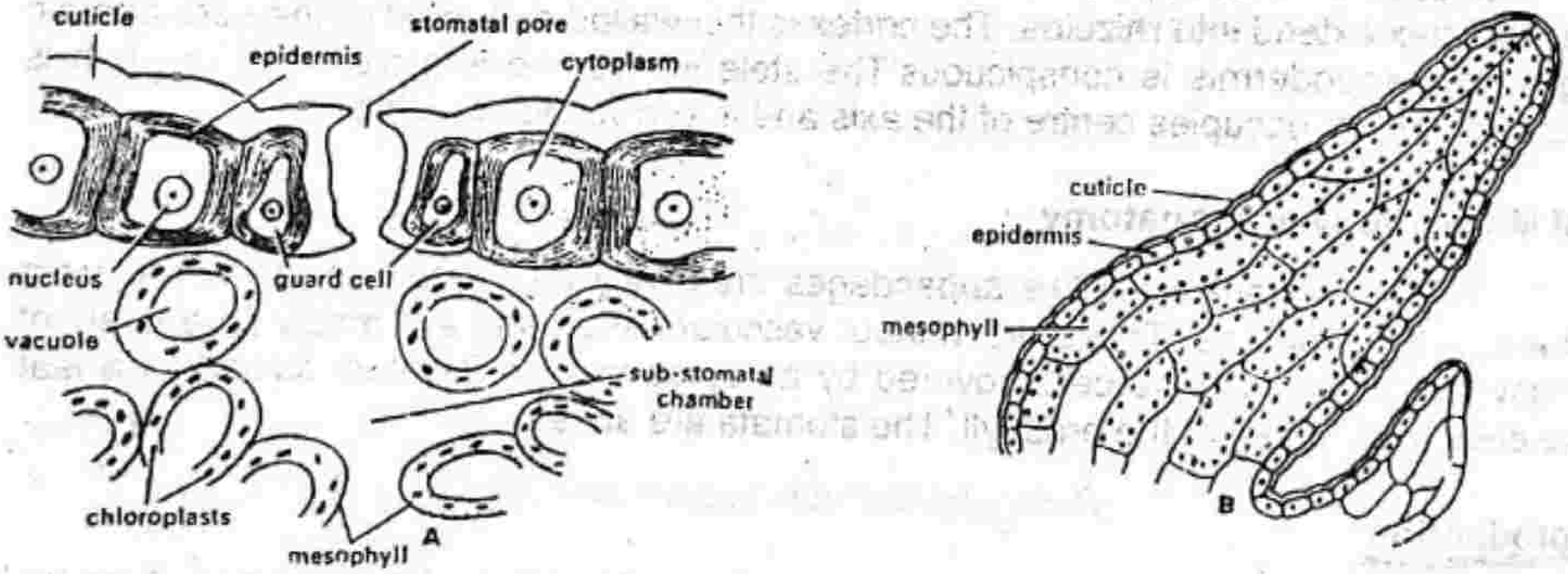


Fig. 7.10: Psilotum — Longitudinal section of a leaf.

Structure and Development of Synangium

Each synagium is trilobed, stalked structure borne at the apex of a short lateral branch. A bilobed appendage is present at the base of each synangium which curve about the synangium and its stalk and surrounds it.

The development of the synagium is eusporangiate. Three superficial cells just below the apex of the branch act as sporangial initials. Each initials divides by a periclinal wall into an outer primary wall initial which divides by repeated anticlinal and periclinal divisions to form a several layered wall of the sporangium; and inner primary sporogenous initial. The primary sporogenous initial undergoes repeated divisions to give rise a mass of sporogenous cells. As the sporangium matures, irregular groups of cells in sporogenous tissue divide repeatedly to give rise to spore mother cells. The remaining sporogenous cells disintegrate and form a plasmodial mass which provide nutrition to the developing spores. Thus, there is no definite tapetum. A mature spore is colourless, kidney-shaped and have transparent walls.

During spore formation, the walls of synangium undergo thickening by deposition of additional wall material. However, the three vertical walls remain thin and act as dehiscence sites.

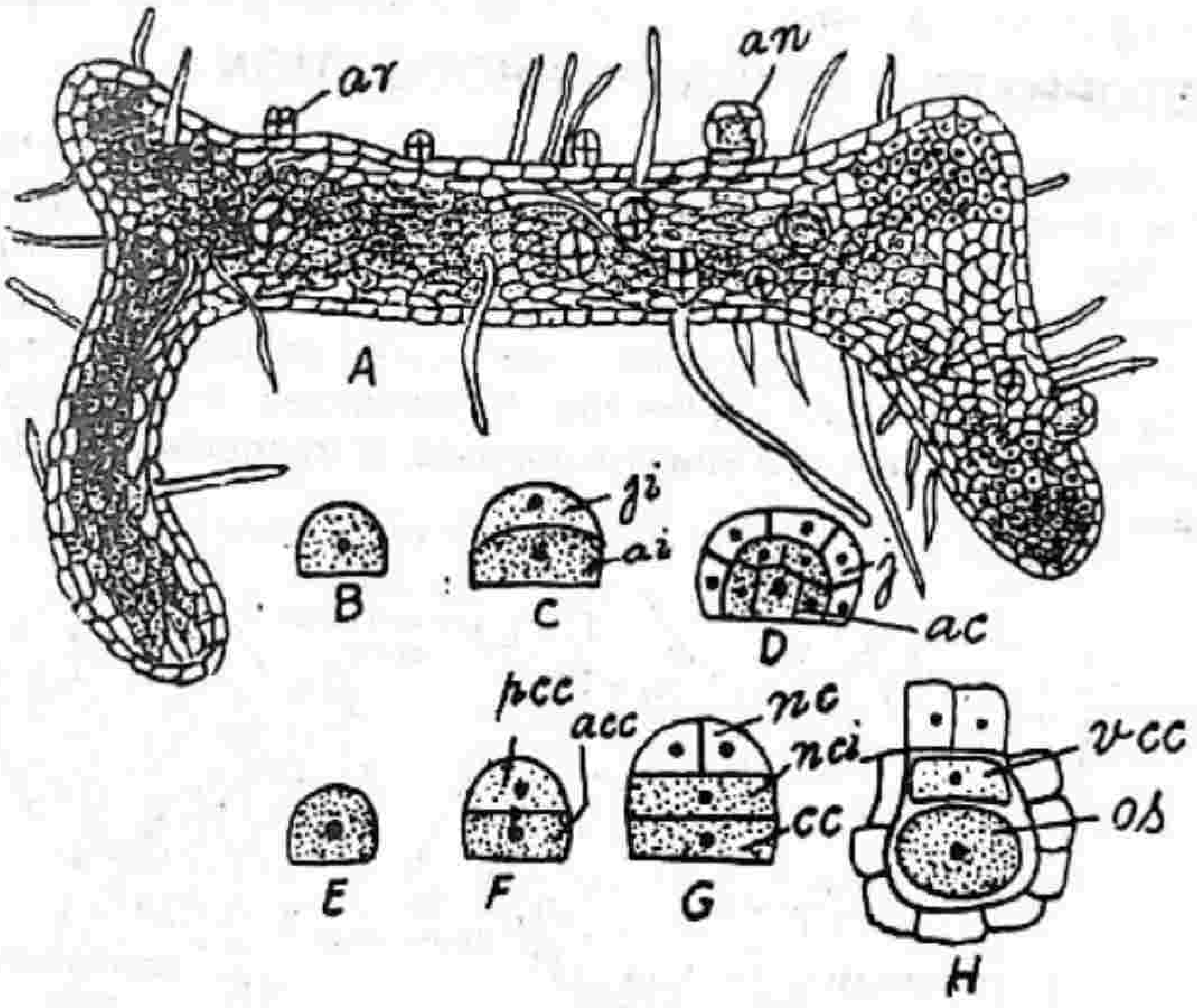


Fig. 7.11: Psilotum — Successive stages in the development of a synangium.

Nature of the Synangium

Various views have been expressed regarding the nature of the synangium.

i. According to one view the trilobed synangium is a fusion product of two or more sporangia.

ii. The second group of botanists consider it as trilocular sporangium.

iii. The third school of thought interprets it as a trilocular sporangium that developed at the apex of a short or lateral branch, therefore cauline in nature.

The synangium in *Psilotum* is generally interpreted as a sporangiophore fused with a subtending bract. The early developmental stages show that there are separate sporangia and not one septate sporangium. The developmental pattern of synangium differ from marattiaceous ferns possessing synangia. The presence of vascular tissue in synangium support the concept that it is cauline in nature, i. e., has developed from an axis. Also. the regular occurrence of vascular supply in the short pedicel subtending the synangium, and in some cases presence of a fruiting body with elongate pedicels suggest that the pedicels are homologous to the sporangiophores in Equisetum. Also the sporangial axis of *Psilotum* can be compared with that of Equisetum.

iv. Another thought provocating concept was suggested by Bierhorst (1956). According to him each unit in a synangium represents a condensed fertile axis. The synangium in *Psilotum* can be considered homologous to fertile portions of Psilophytales (Rhynia) where one arm of a dichotomous branch is fertile and the other is sterile. A condensation of fertile arm to a condition where there are very short dichotomies terminating in sporangia would result in synangium. The flattening of sterile arm would result in bract subtending the synangium.

THE GAMETOPHYTE — SEXUAL REPRODUCTION

The spore germinates to form a protallus. The development of prothallus is by an apical cell. The gametophytes are small, cylindrical and dichotomously branched usually. The entire surface of the thallus is covered with rhizoids. They grow on trunks of tree ferns or in crevices of rocks, sometimes it is subterranean. Because of its smaller size and simpler organization, the gametophyte is also called prothallus. The growth of the prothallus is by apical cells located at the tips of dichotomies. All the cells of prothallus are parenchymatous and there is a strand composed of tracheids extending back from the growing apex.

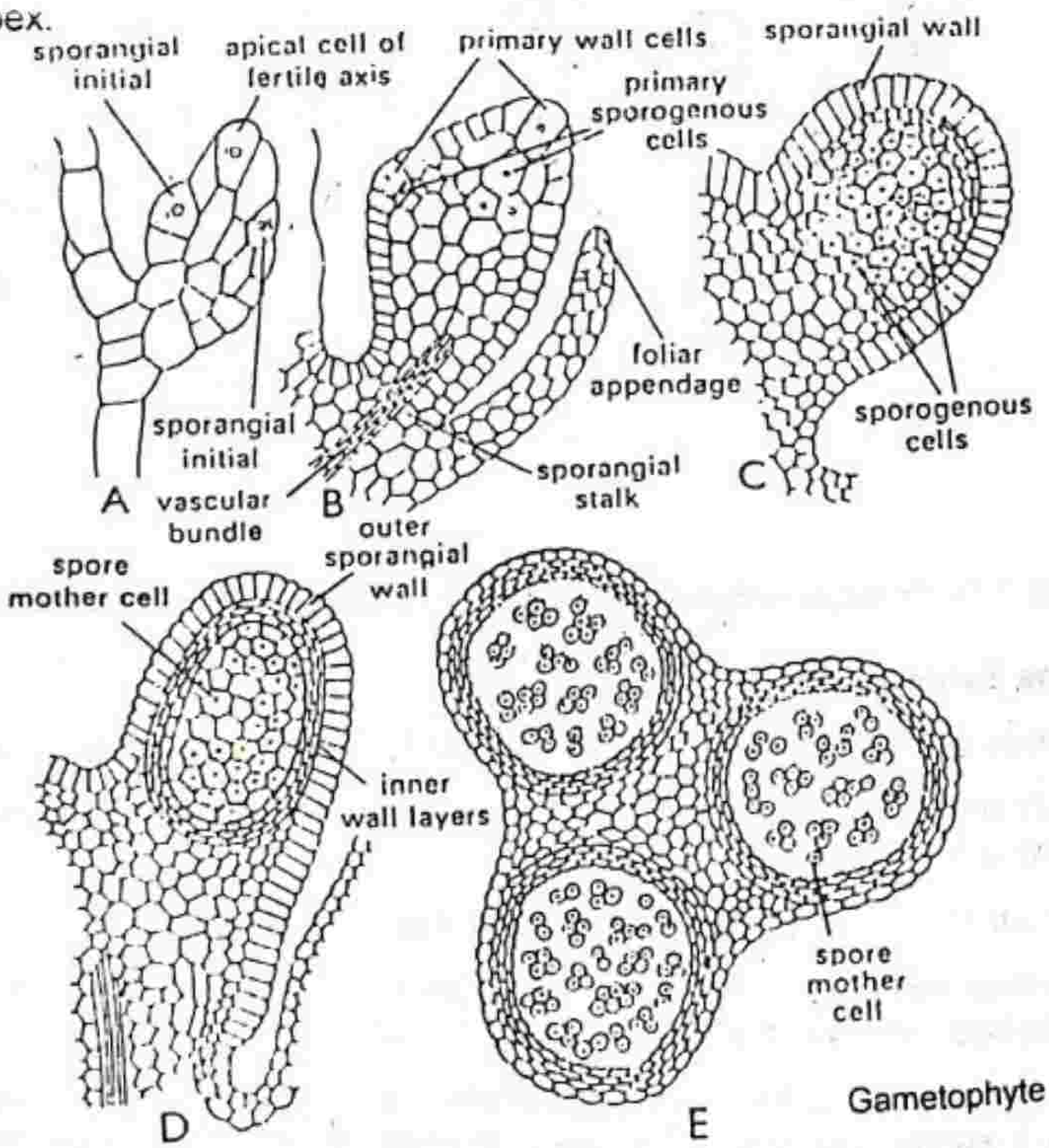


Fig. 7.11: Gametophyte of Psilotum

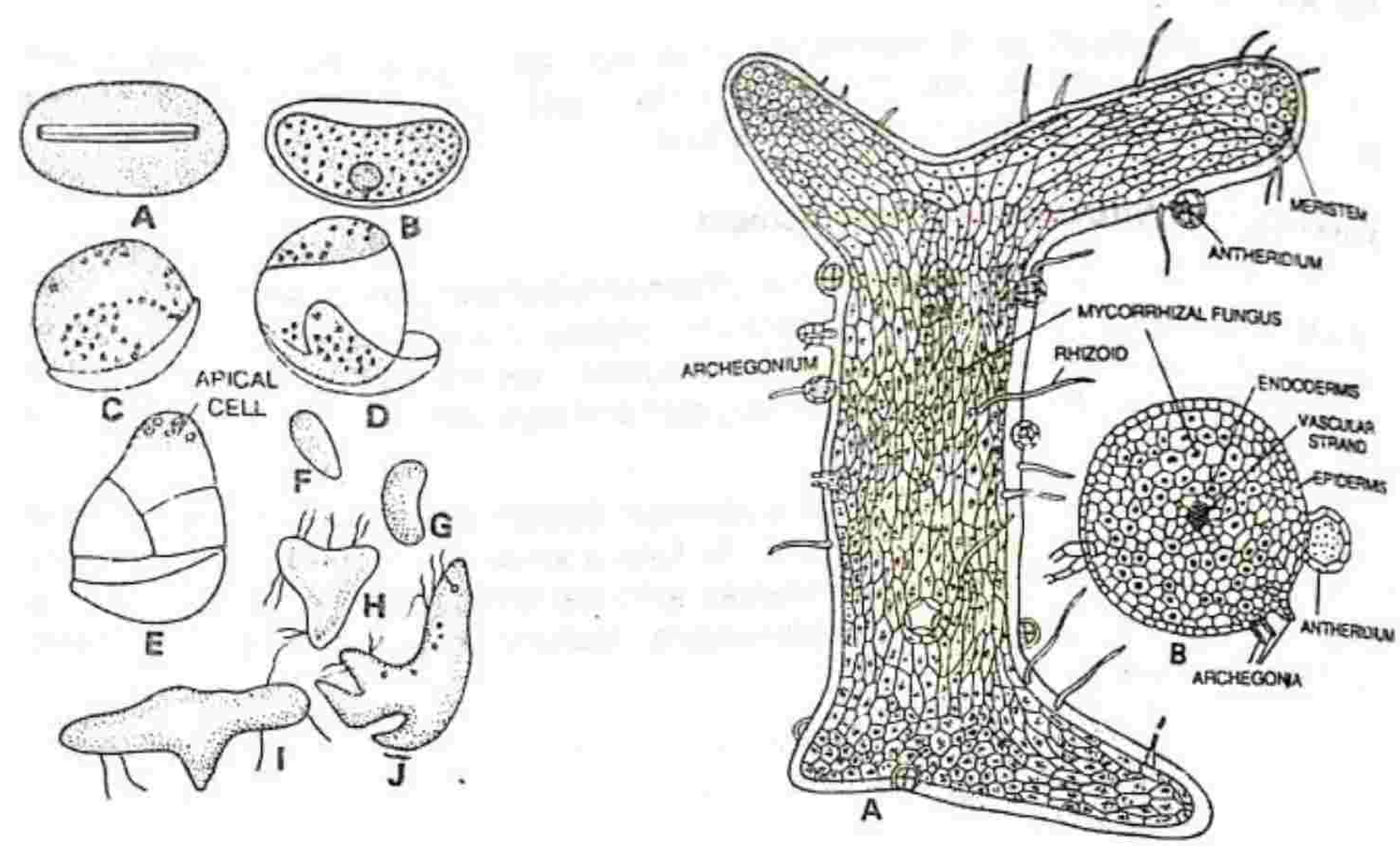
The Sex Organs

The gametophyte is homothallic and the sex organs, the antheridia and archegonia, are scattered over the entire surface and intermingled. The sex organs develop from superficial cells of the gametophyte.

Antheridium — Structure and Development

Each antheridium is hemispherical (dome-shaped) and present slightly above the surface of gametophyte. A mature antheridium consists of a single layer of sterile jacket cells enclosing a small number of coiled, multiflagellate sperms. At the center of jacket, a triangular opercular cell is present. It disintegrates and provides an opening for escape of male sperms.

The antheridial initial divides by a periclinal division to form an outer jacket initial which divides further by anticlinal divisions to form a single-layered jacket; and primary spermatogenous cell that undergoes repeated anticlinal and periclinal divisions to form a mass of spermatocytes. Each spermatocyte metamorphose into spirally coiled multiflagellate male sperm.



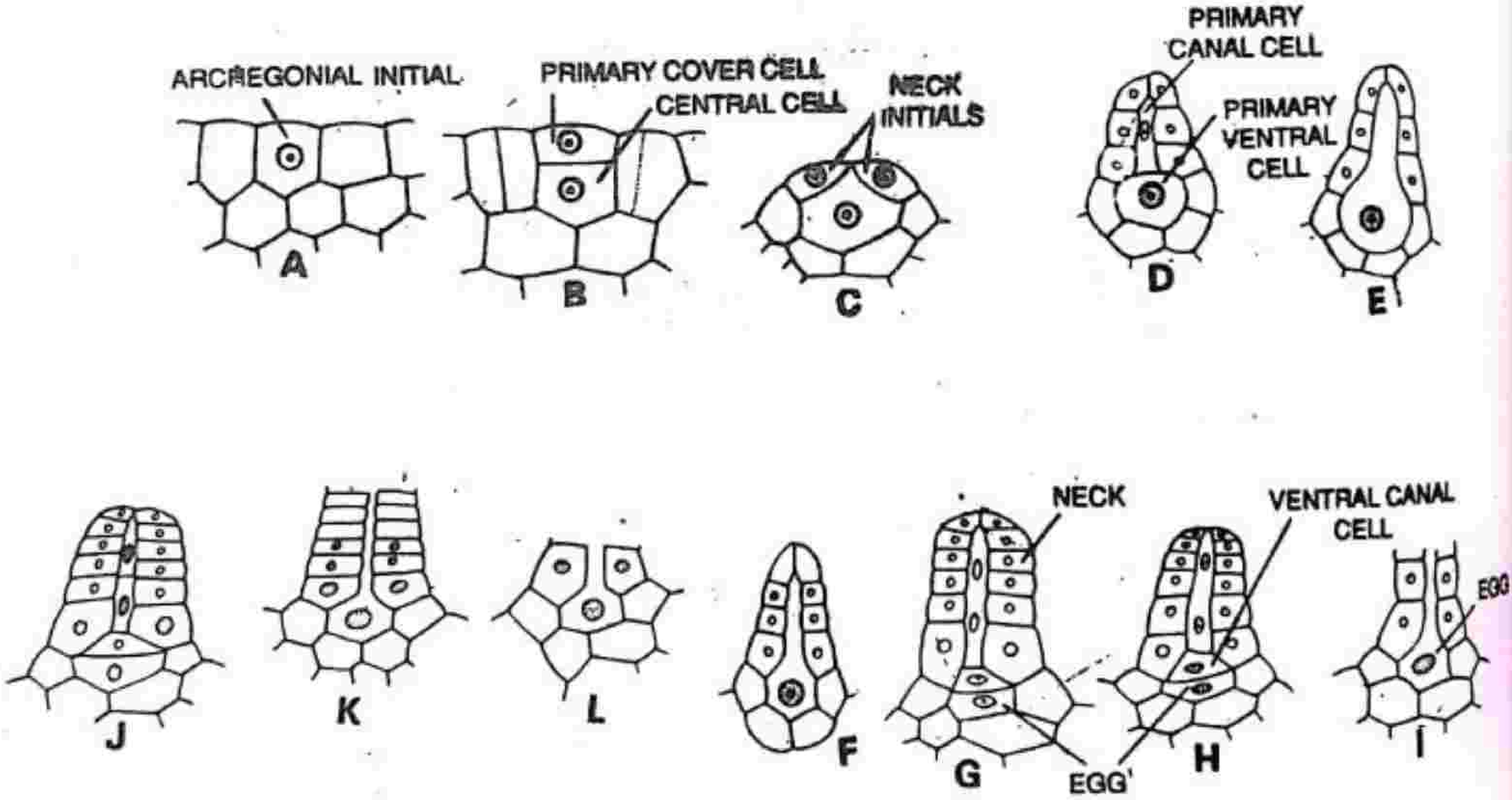


Fig. 7.12: Psilotum — A. Successive stages of spore germination and development of prothallus; B. A mature prothallus; C. Successive stages in the development of an antheridium.

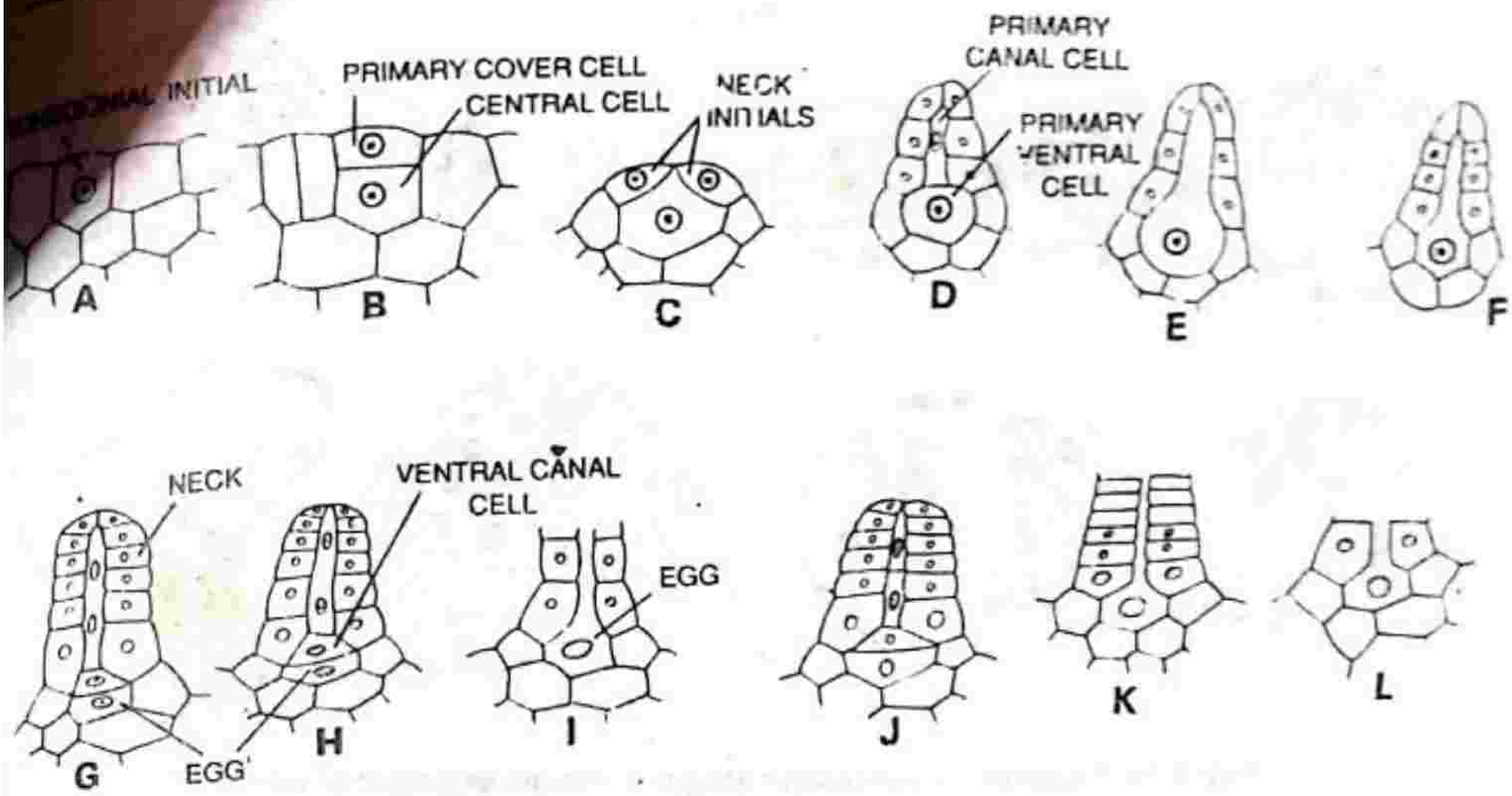


Fig. 7.13: Psilotum — Successive stages in the development of an archegonium.

Fertilization

The neck cells disintegrate to leave a passage for the entry of male sperms into the venter of the archegonium. The male sperms enter the archegonium and of one of these succeed in fertilizing the egg to form the zygote.

Embryo Development

The zygote divides in a plane at right angles to the long axis of the archegonium to form a hypobasal and an epibasal cell towards the neck. The hypobasal cell develops into foot of the embryo. The epibasal cell develops into embryonic stem.

The development of foot starts with repeated divisions in an irregular manner that result in a cylinder of cells. The superficial cells of this cylinder elongate into short haustoria which enter prothallus tissue and absorb nutrients.

The development of shoot begins with a vertical division in epibasal cell. The two daughter cells divide by a transverse division, but further divisions take place in irregular manner. An apical cell is established at distal end which brings further growth. The sporophyte develops rhizoids here and there on its surface and becomes infected with a myocardial fungus. It is capable of nourishing itself now and act as an independent plant.

An abscission layer is formed between the foot and embryonic stem which causes separation of sporophyte. The primary stem is branched rhizome. Some branches move upward and emerge above the soil to act as aerial branches.

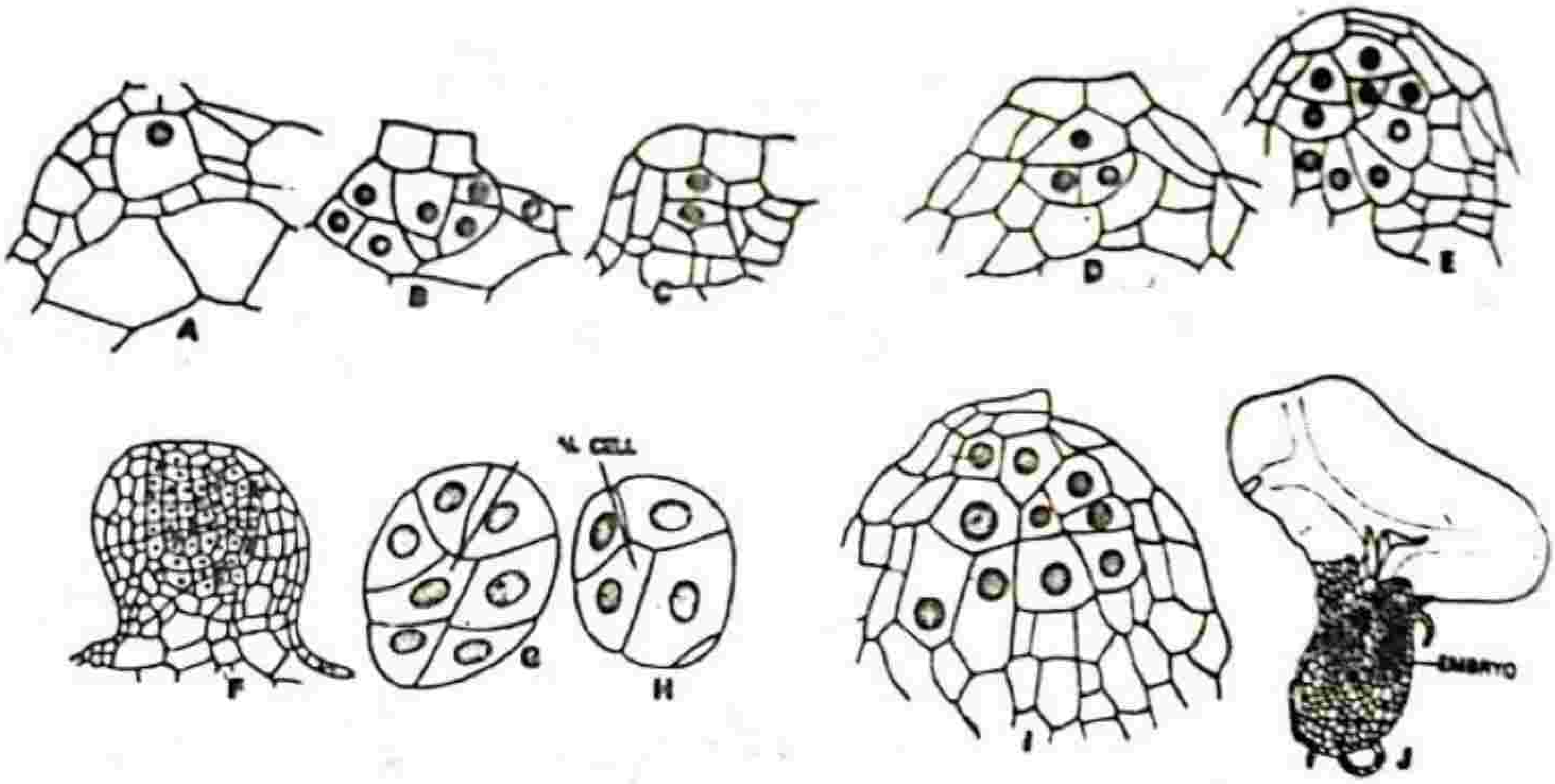


Fig. 7.14: Psilotum — Successive stages in the development of embryo.

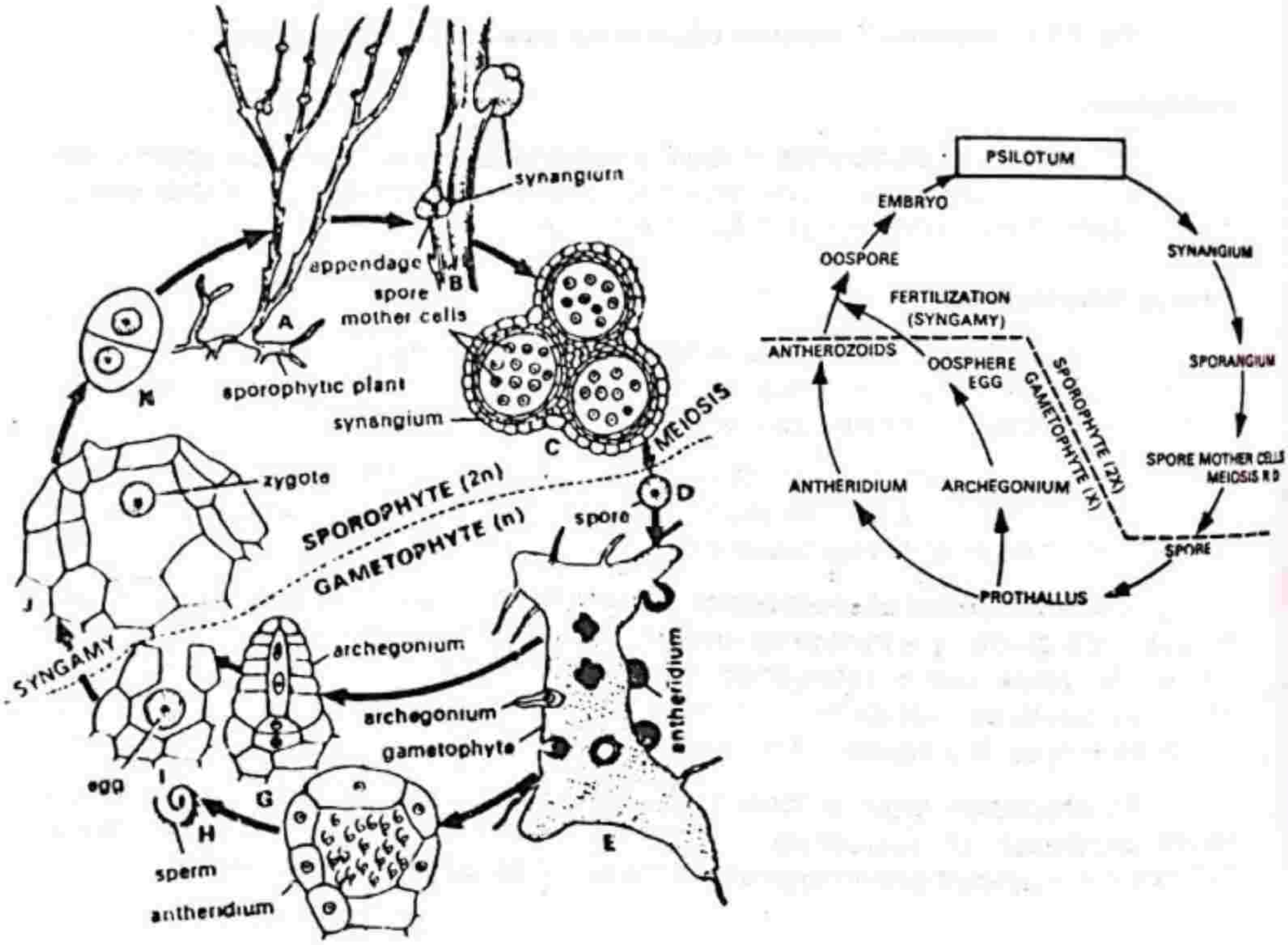


Fig. 7.15: Psilotum — Life cycle.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are psilophyta.
2. What is whisk fern.
3. Which type of stele is found in psilotum.
4. What is rhizome.
5. What is synangium.
6. Draw gametophyte of psilotum.
7. Is gametophyte of psilotum is photosynthetic.
8. What is embryonic stem.
9. What is dichotomy.
10. Draw diagram of gametophyte of psilotum.

B. Long Questions

1. Describe gametophyte of psilotum.
2. Describe internal structure of stem of psilotum.
3. Describe life history of psilotum.
4. Write note of development of synengium.
5. Describe gametophyte of psilotum.

MICROPHYLLOPHYTA *(LYCOPOSIDA)*

The division includes both living and extinct genera and has a very long evolutionary history that extends from the Paleozoic till date. The members of the division are characterized by presence of microphyllous leaves; possess roots; and the sporangia are associated with fertile leaves, the sporophylls. Because of their small size, moss-like leaves and aggregation of sporophylls into terminal groups, the members of this division are commonly called spike mosses or club mosses.There are four living genera with more than 900 species which occur in various parts of the world under varied climatic conditions. The living genera consists of Lycopodium (club-moss), Selaginella (spike-moss), *Phylloglossum* (a small tuberous plant) and Isoetes. The extinct genera are *Baragwanthia, Protolepidodendron, Lycopidites, Lepidodendron, Sigillaria* and *Selaginellites.*

GENERAL ACCOUNT

1. The Microphyllophyta (Lycopsida) is a well defined group of vascular plants consisting of fossil and living representatives. The known history of the group extends from the Paleozoic era to the present.
2. The members of the division can be classified as small plants, some being erect, others living as epiphytes or growing as creepers along the ground or producing underground rhizomes. Some of the ancient lycopods were good sized trees (Lepidodendron).
3. All the lycopods have a sporophyte differentiated into stem, leaves and roots.
4. The stem may be dichotomously branched or modified into pseudomonopodium.
5. The leaves of living genera are generally small with a single vein (microphyllous). The arrangement of leaves is spiral mostly, however in certain species these may be arranged in opposite pairs or whorls. Each leaf of certain genera (*Selaginella, Lepidodendron, Isoetes)* has a tongue-like appendage on its adaxial side called ligule.
6. In most genera the roots are adventitious arising from rhizomes (*Lycopodium*) or specialized structures, the rhizopohores (*Selaginella*). However, in Isoetes the root is primary and perennial.
7. The stele in most living genera is protostele in the form of a solid or medullated vascular cylinder. The primary xylem is exarch in development and consists of tracheids. In other genera the stele is siphonostele or polystele (Selaginella). However, in all the cases the leaf gaps are absent.
8. The secondary growth is absent except in Isoetes.
9. The members of the division exhibit alternation of generations. The dominant phase is sporophyte. The gametophyte is independent but reduced.
10. The sporophyte reproduces by asexual reproduction by formation of spores produced in eusporangiate sporangia.
11. The sporangia are borne either singly in the axil of or attached to the adaxial surface of fertile leaves, the sporophylls.
12. In most lycopods the sporophylls are arranged in strobili (Lycopodium, Selaginella).
13. Both homosporous (Lycopodium) and heterosporous (Selaginella) lycopods are found. The heterosporous forms produce two different types of spores, the microspores (small-sized) and megaspores (large-sized).

14. The heterosporous forms produce endosporic gametophytes and the homosporous forms produce only exosporic gametophytes.
15. The gametophytes are reduced and each is generally called a prothallus.
16. The prothallus in *Lycopodium* may be erect and cylindrical and grows at the surface of the ground; subterranean, tuberous and saprotrophic; or subterranean, saprotrophic and repeatedly branched.
17. In *Selaginella*, the male and female gametophytes are separate.
18. The male gametophyte is extremely reduced and the wall of the antheridium degenerate before the spore wall cracks open and the sperm mother cells lie freely within the spore wall. It is released at 13-cell stage.
19. The mature female gametophyte consists of an upper cushion-like generative region and a lower food-filled nutritive region. Archegonia develop in the generative region.
20. The embryo is quadrant type.

SELAGINELLA (*Club Moss Or Spike Moss)*

Taxonomic Position

Division:	Lycophyta
Class:	Ligulopsida
Order:	Selaginellalies
Family:	Selaginellaceae
Genus:	*Selaginella*

Selaginella (L. Selago=name of a plant resembling juniper + ella=diminutive), commonly called a club moss or spike moss, is worldwide in distribution. However, it is abundant in tropics growing on ground in damp and shady place. Certain species are xerophytic. Most commonly found and widely studied species is *Selaginella kraussiana*.

Vegetative Morphology

The plant is a sporophyte and differentiated into root, stem and leaves.

Stem

The stem is green, dorsiventral and prostrate with short erect branches. The branches are arranged dichotomously or in pseudomonopodial manner depending upon species. The shoot apex consists of a single apical cell in most cases.

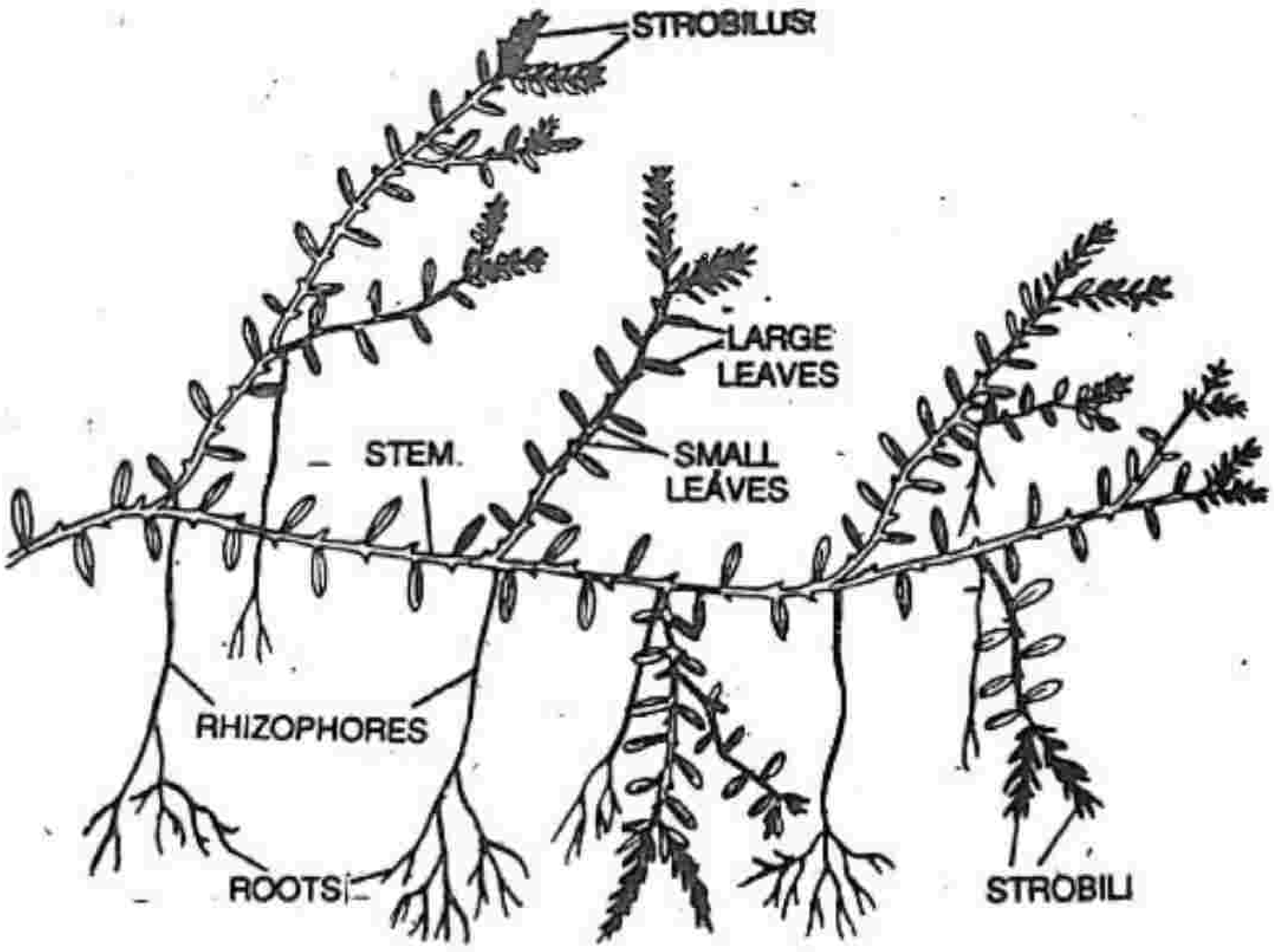


Fig. 7.16: Selaginella — Vegetative morphology.

Rhizophores

In many species, leafless and colourless branches arise from the prostrate stem near the point of branching. These branches grow downwards and bear a group of adventitious roots at their tips. They are called rhizophores. There are many views regarding the nature of the rhizophores. Some consider these as branches, others a root, and still others as an organ sui generis. However, recent studies regard these as adventitious roots that fork repeatedly and dichotomously near their apices.

Leaves

The leaves are small and single-veined (microphylls) and may be alike in size (isophyllous) or they are of two different sizes (anisophyllous). The anisophyllous leaves are borne in pairs. The smaller leaf of each pair is inserted on the dorsal side of the stem, and the larger leaf is inserted on the ventral side. There is a small membranous outgrowth, the ligule, on the adaxial side of the leaf near the base. It is considered as vestigial organ, however some are of the view that it is water-secreting or water-absorbing structure that keep the leaf moist.

Root

The root of young sporophyte is primary root, whereas all other roots are adventitious. The adventitious roots occur at the tips of rhizophores. In *Selaginella kraussiana* aerial roots with well developed caps and cutinized epidermal cells exist. These enter the soil.

STEM ANATOMY

Epidermis

The outermost layer is one cell thick epidermis. It is formed of thin-walled rectangular cells. It is covered with thin cuticle.

Cortex

Beneath the epidermis many layered cortex is present. The outer 2-4 layers of cortex are formed of thick-walled sclerenchyma cells and known as hypodermis. Below it the cortex is made up of thin-walled parenchyma cells containing chloroplasts. These cells enclose small intercellular spaces.

In older stems the central portion of stem is separated from the cortex by a cylindrical cavity usually called air space.

Endodermis

The cortex and central tissue is connected by radially elongated endodermal cells called trabeculae. They contain Casparian strips, thus the trabeculae are modified endodermal cells.

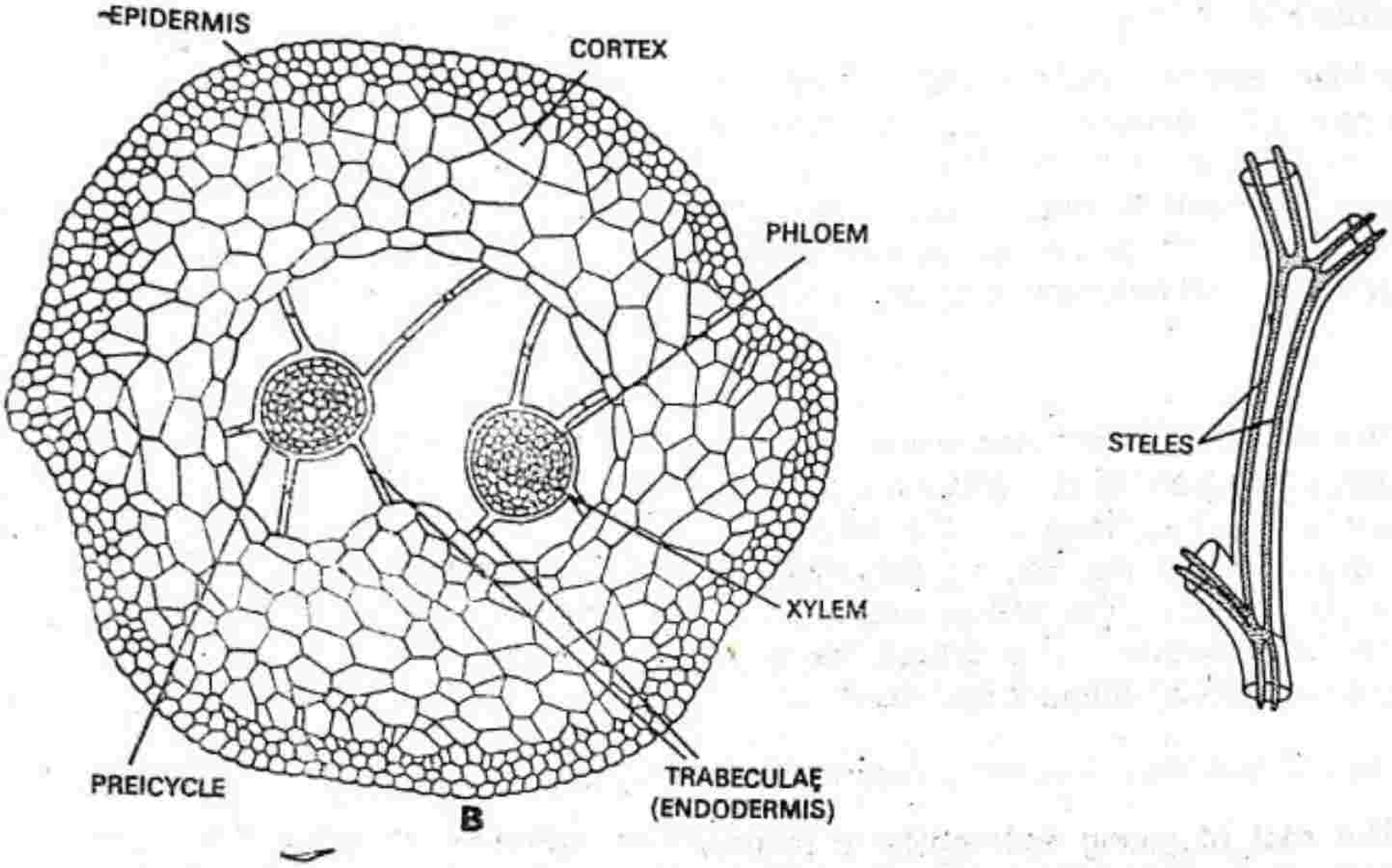


Fig. 7.17: Selaginella — Internal structure of stem.

Stelar System

Pericycle

The stele comprises of a single layer of pericycle formed of thin-walled cells, encircling the vascular tissue, xylem and phloem.

Phloem

Next to pericycle is phloem composed of sieve cells and phloem parenchyma. Companion cells are absent. Phloem surrounds the xylem completely.

Xylem

Xylem occupies the center of the stem. The xylem consists of protoxylem and metaxylem which are composed of tracheids and xylem parenchyma cells. The vessels and fibres are absent. Major portion of the stele is formed of metaxylem whereas the protoxylem occupies the two ends of the metaxylem.

Rhizophore Anatomy

The outermost layer in rhizophore is epidermis. It is single layered and composed of thick-walled cells. Beneath the epidermis there is a broad cortex which is differentiated into an outer thick-walled region, the hypodermis; and inner thin-walled parenchymatous region. The innermost layer of cortex is endodermis. The endodermis is followed by thin-walled pericycle that surrounds the vascular tissue. The stele is protostele. The xylem occupies the center of the axis and phloem surrounds the xylem.

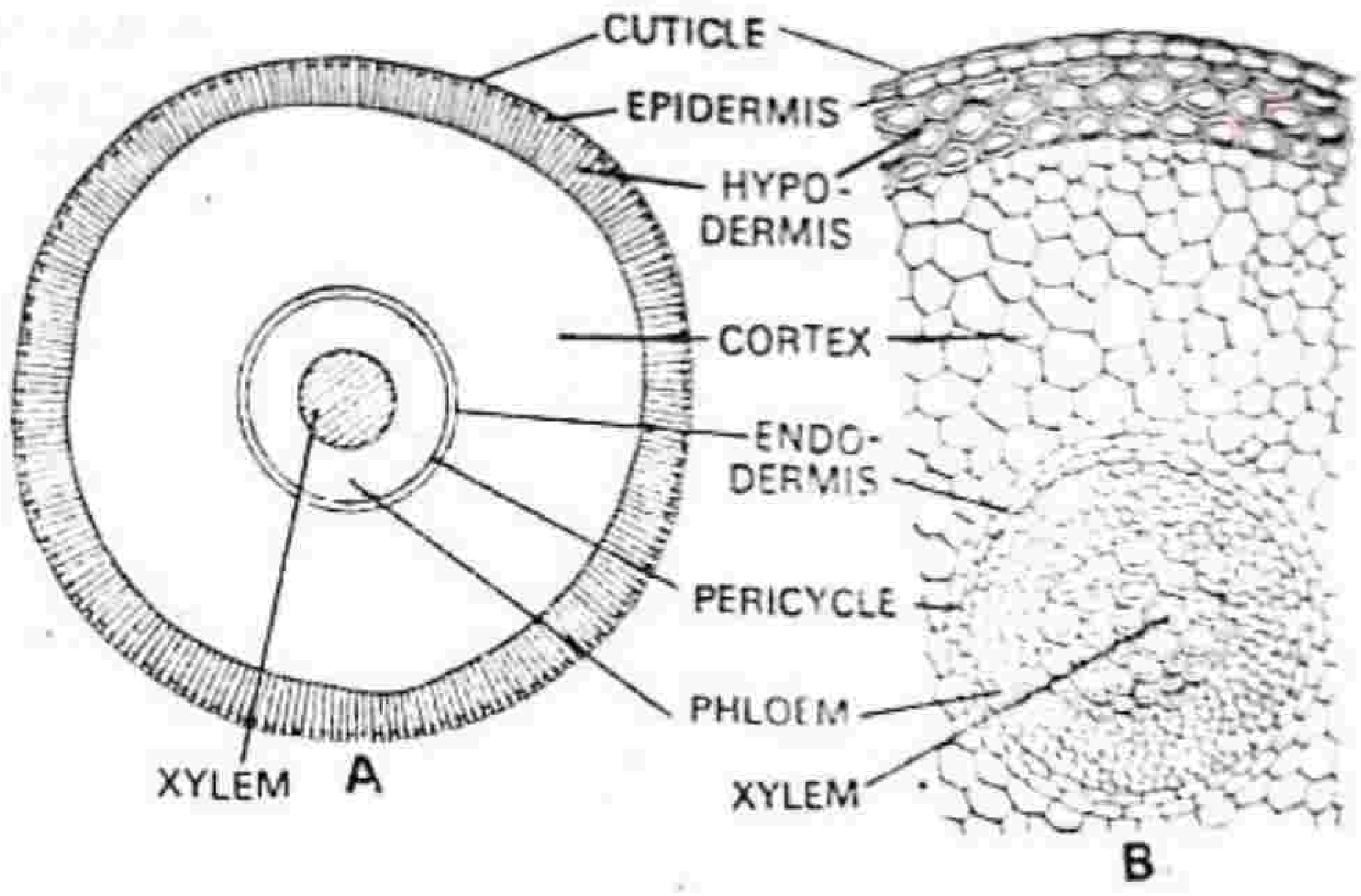


Fig. 7.18: Selaginella — Internal structure of rhizophore.

Leaf Anatomy

The upper and lower surfaces of leaf are covered with distinct upper and lower epidermis. These are one cell in thickness and their cells contain chloroplasts. The stomata are present in both upper and lower epidermis, but in majority of species these are restricted to lower epidermis. In between epidermis layers, meosphyll tissue composed of thin-walled parenchyma cells is present. The cells contain chloroplasts and enclose small or large air spaces. The vascular tissue occupies the center of the leaf. Xylem is composed of tracheids only and phloem comprises of a few sieve cells and many parenchyma cells. Phloem surrounds the xylem. The vascular bundle (vein) is surrounded by a single layer of cells forming the bundle sheath.

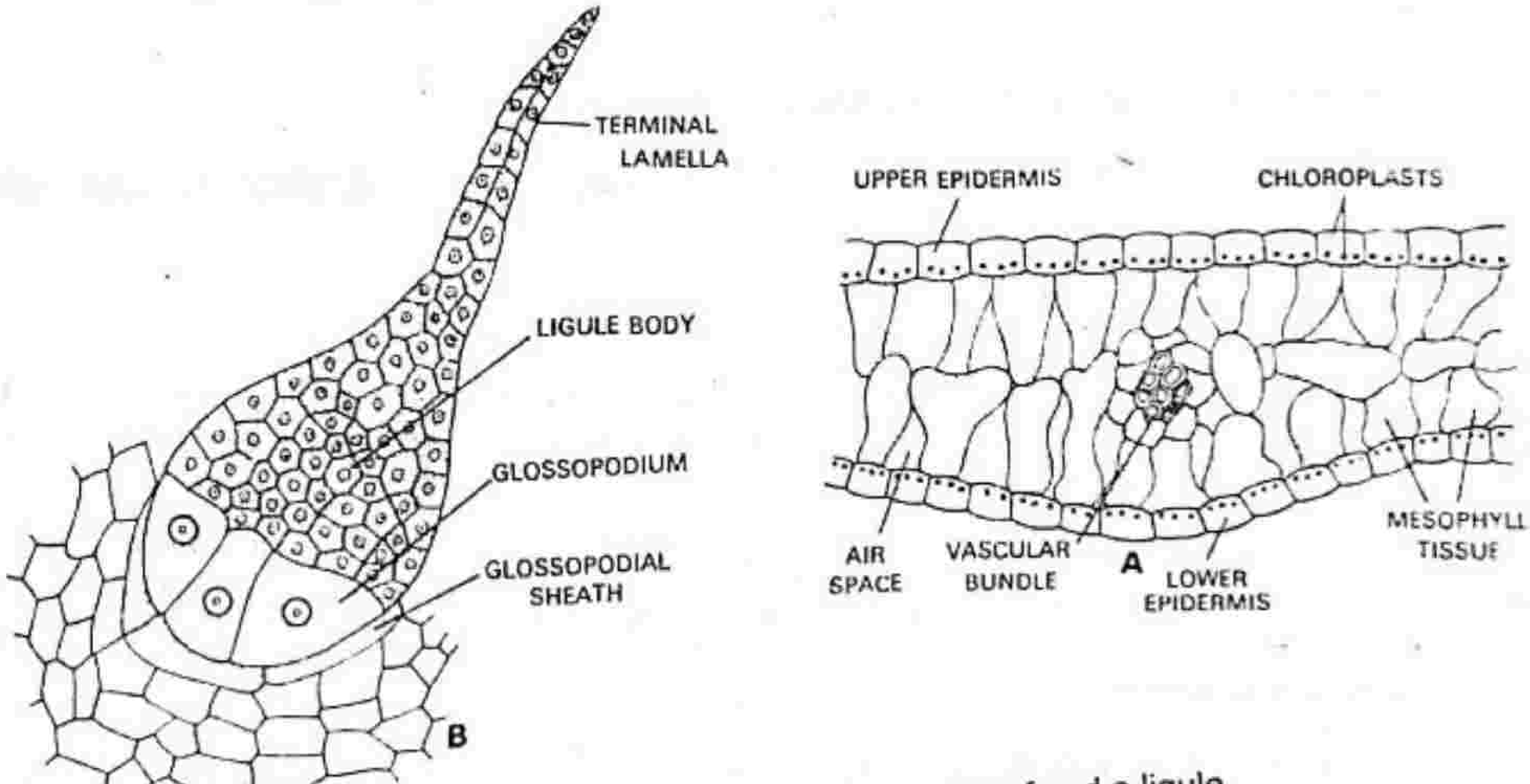


Fig. 7.19: Selaginella — Internal structure of leaf and a ligule.

Root Anatomy

The root is bounded by a single-layered epidermis which is covered by a thin layer of cuticle. Root hairs arise from epidermal cells. Beneath the epidermis there is a wide zone of cortex. It is differentiated into outer hypodermis composed of sclerenchymatous cells and inner thin-walled region. The innermost layer of cortex is endodermis. It is usually inconspicuous. Next to endodermis is single-layered pericycle that surrounds the vascular tissue. The stele is protostele. Xylem occupies the center while the phloem surrounds it.

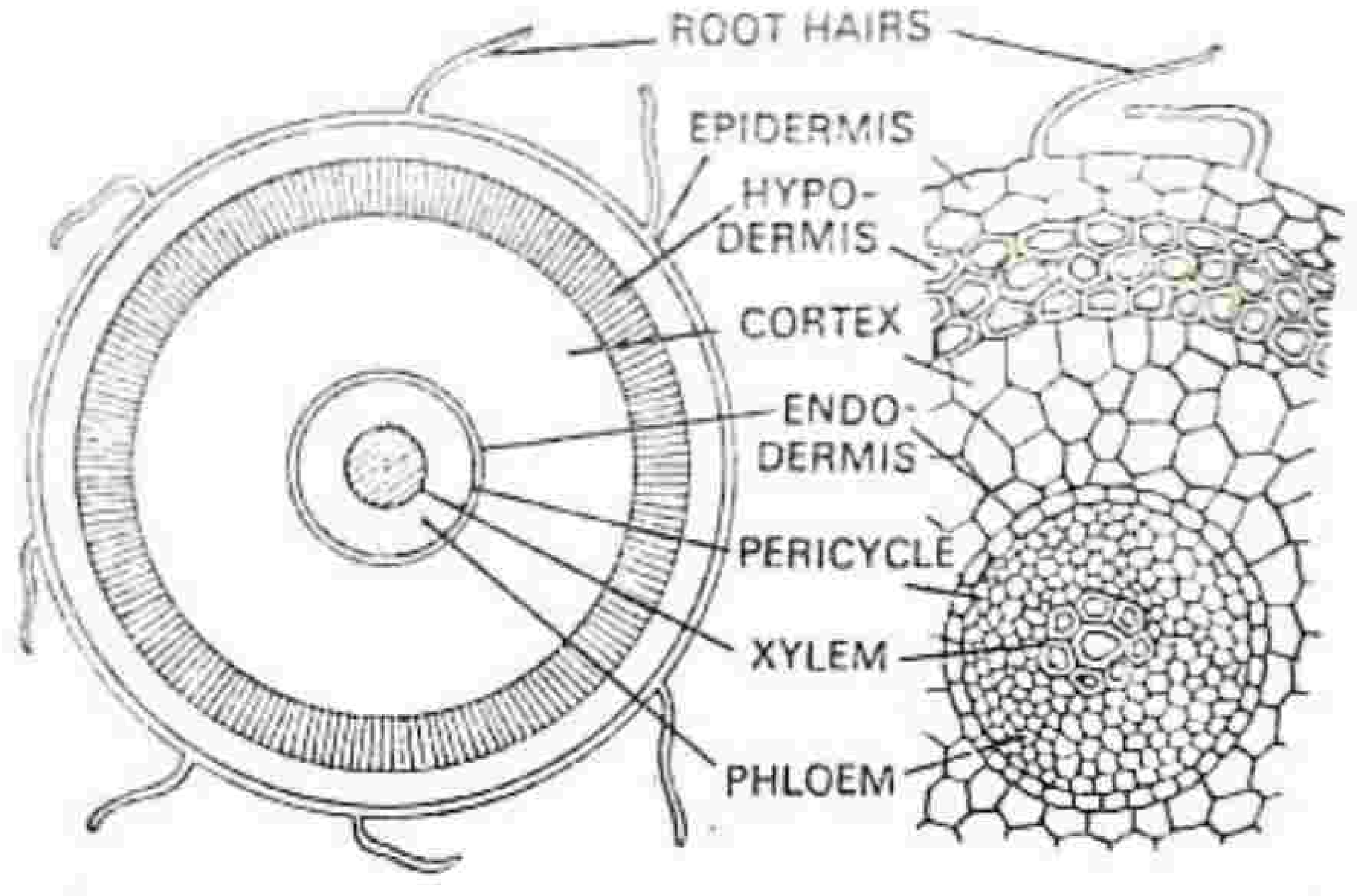


Fig. 7.20: Selaginella — Internal structure of root.

Reproduction

The life cycle in Selaginella is characterized by alternation of generations. Both the spore- and gamete-producing generations are independent. Some species reproduce by vegetative multiplication.

The Sporophyte — Vegetative and Asexual Reproduction

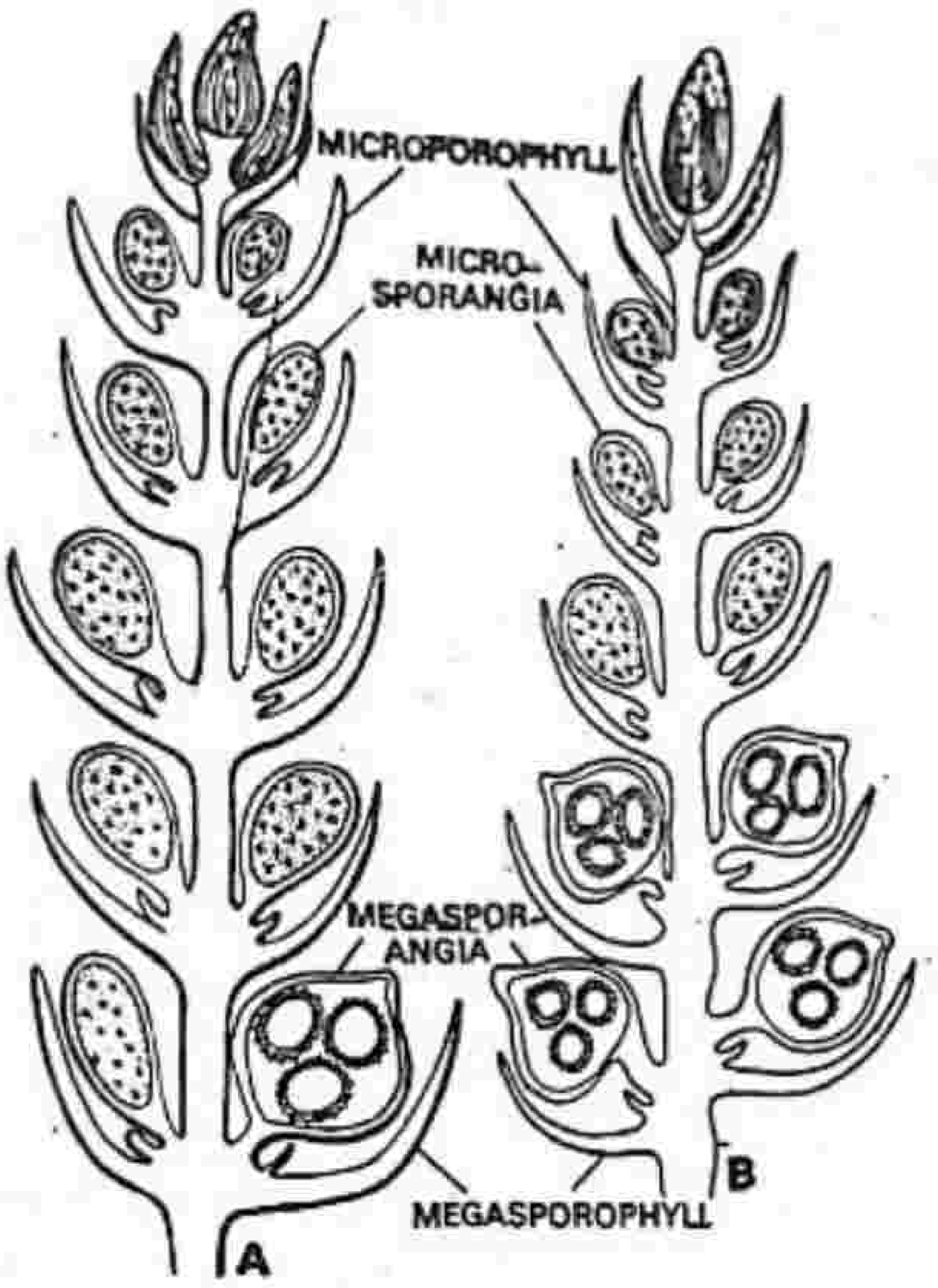
The sporophyte reproduces both by vegetative multiplication and spore formation.

Vegetative Reproduction

Some *Selaginella* species reproduce vegetatively by development of adventitious branches which separate from the parent plant and develop into new sporophytes. Other species produce tubers during unfvaourable conditions for growth. These tubers develop into new plants on return of favourable conditions. Still other species develop resting buds at the ends of aerial branches. These are surrounded by leaves. These can survive adverse conditions and develop into new plants when conditions are suitable for growth.

Asexual Reproduction

All *Selaginella* species are heterosporous, i. e., these produce morphologically and functionally distinct spores of two different kinds, the smaller microspores and the larger megaspores. These spores are produced in separate sporangia known as microsporangia and megasporangia respectively.



Sporangioferous Spike

The sporangia are borne in the axils of ligulate leaves called sporophylls. The sporophylls form definite structures called strobili at the ends of shoots. The sporophylls are almost like vegetative leaves and arranged spirally upon the axis of the strobilus. A single stalked sporangium is present between the ligule and base of the sporophyll. The arrangement of sporophylls in a strobilus is just like that of bracts in a spike (an inflorescence in angiosperms), therefore the strobilus is also called sporangioferous spike.

Structure of Sporangia

The microsporangia are small, stalked and variously shaped, mostly oval; whereas the megasporangia are stalked and four-lobed. Both micro- and megasporangium consist of a two-layered sporangium wall surrounding tapetum and sporogenous tissue. The tapetum develops from innermost layer of sporangium wall.

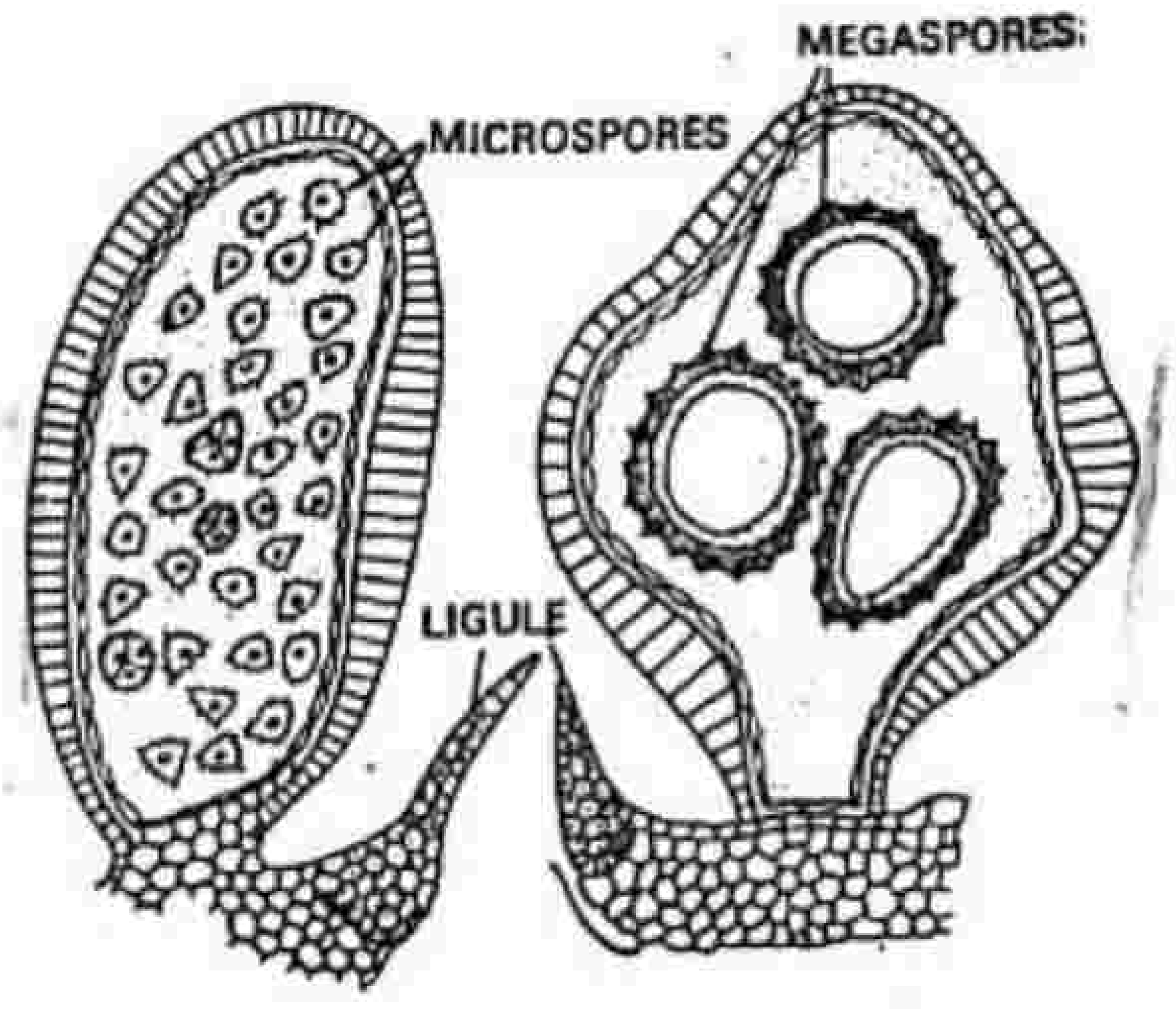


Fig. 7.22:

Both the sporangia differ in their size, position in the strobilus, and number and size of spores. The megasporangia are larger than microsporangia, present at the base of the strobilus, and contain few spores of larger size. Both the sporangia dehisce by formation of a vertical cleft in the wall and release the spores.

Development of Sporangia

The development of micro- and megasporangia is identical upto formation of sporocytes. The sporangium arises from a superficial cell called sporangial initial. It divides by a periclinal division into an outer jacket initial which divides further periclinally to give rise to a two-layered sporangium wall, and an inner archesporial cell. It undergoes repeated vertical and transverse division to produce a mass of sporogenous cells. These cells continue to divide and the last generation of these cells is spore mother cells. The outermost layer of sporogenous cells act as tapetum.

The development in both micro- and megasporangium is the same. However, further development differs in that:

i. In microsporangia, the spore mother cells separate, about 10-20% cells disintegrate and the rest develop into tetrads of microspores.

ii. In megasporangium all but one spore mother cells disintegrate. The surviving one undergoes meiosis and produces a tetrad of megaspores. All the megaspores are functional. In some species more than four megaspores have been found suggesting that more than one spore mother cells remain functional.

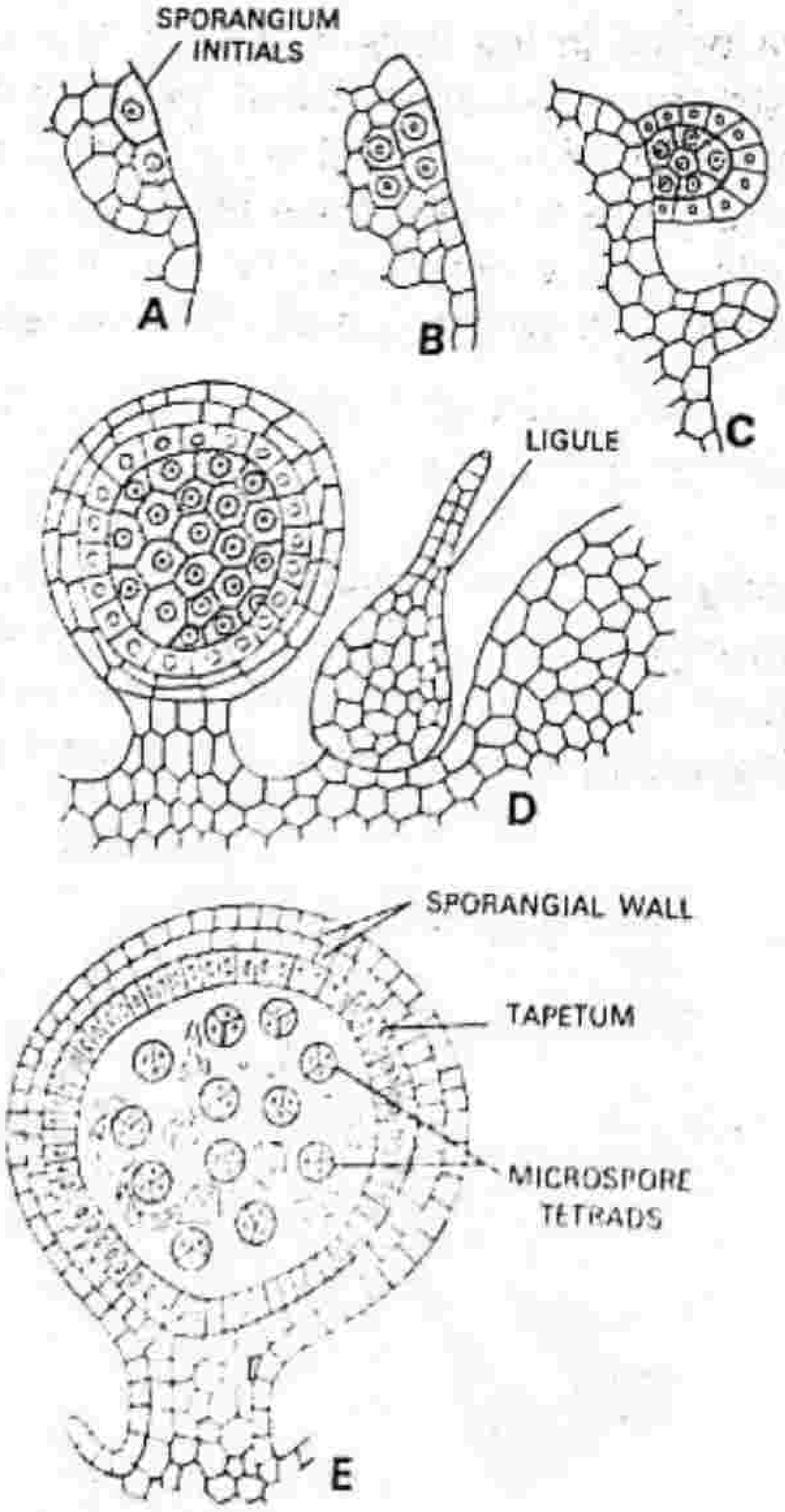


Fig. 7.23: Selaginella — Successive stages in the development of sporangium.

The tapetal cells disintegrate and form a nutritive fluid, the plasmodial fluid. The spore separate, float in this fluid and receive the nutrition.

The Gametophyte — Sexual Reproduction

The microspores and megaspores develop into male and female gametophytes respectively. The germination of spores is precocious, i. e., it starts within the walls of their respective sporangia. The male gametophyte is released at 13-cell stage, whereas the female gametophyte comes out at various stages of development depending upon species.

Male Gametophyte

A microspore is minute, tetahedral and uninucelate. Its protoplast is surrounded by 2-3 layered wall. The outer wall is thick and called exine and the inner wall is thin known as intine. The microspore divides by an unequal division to form a small lens-shaped prothalial cell which does not divide further, and a large antheridial cell. The antheridial cell divides by several divisions in various planes. This results in the formation a sterile eight-celled jacket enclosing four primary spermatogenous cells. This semi-germinated male gametophyte (pollen grain) is released from the sporangium and shed on the ground. Each spermatogenous cell undergoes six successive divisions to produce 128 or 256 sperm mother cells. Each sperm mother cell metamorphoses into a biflagellate male sperm. The jacket cells disintegrate and the spore wall break along triradiate ridge to release male sperms.

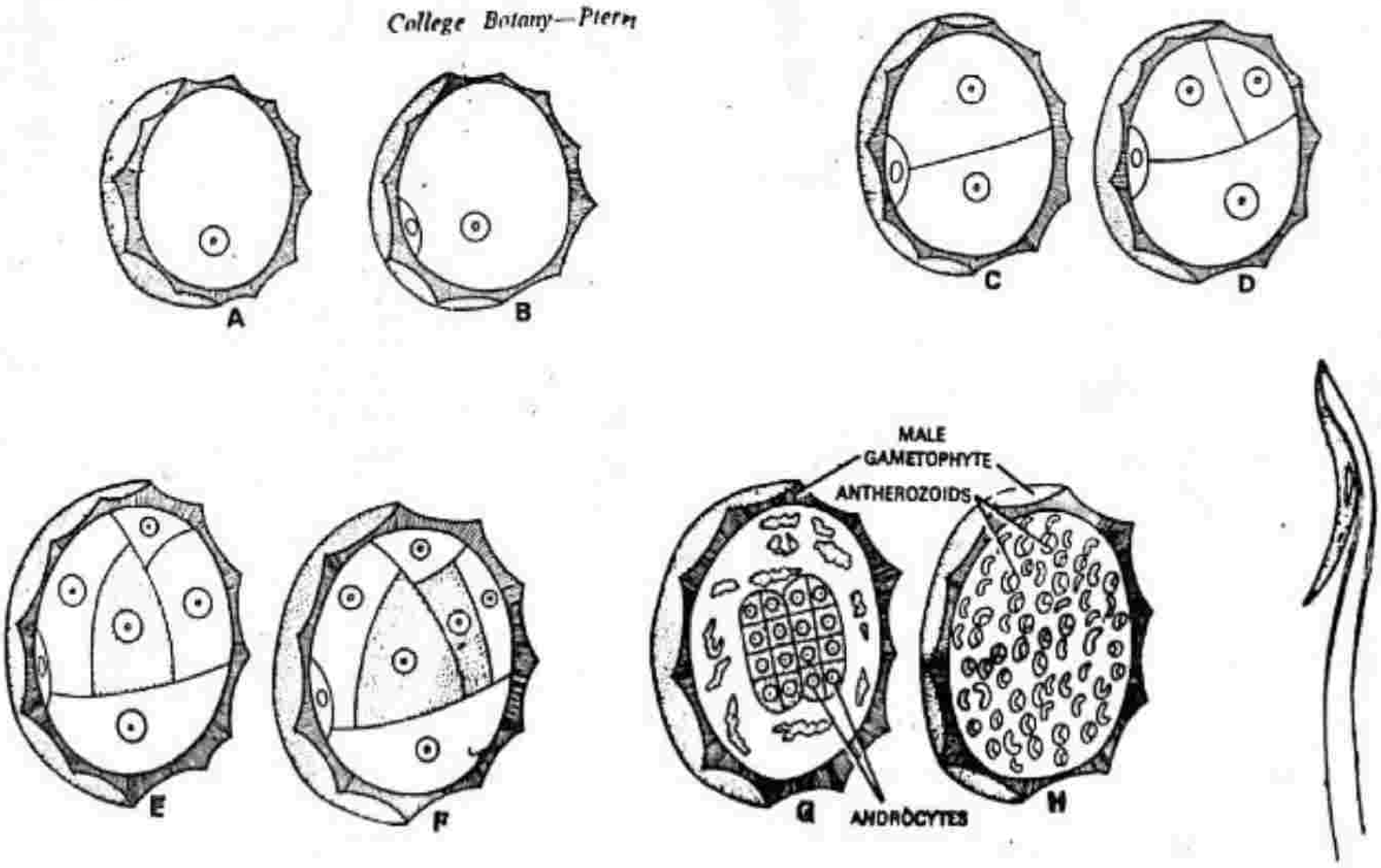

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Fig. 7.24: Selaginella — Successive stages in the development of male gametophyte.

Female Gametophyte

The megaspore enlarges and secretes a two-layered spore wall. The young megaspore develops a large central vacuole surrounded by thin peripheral layer of cytoplasm. The megaspore nucleus undergoes free nuclear division which results in a multinucleate peripheral layer of cytoplasm surrounding the central vacuole. At the same time the cytoplasm increase in amount so that the vacuole becomes smaller and disappears ultimately. The wall formation starts around the free nuclei at the apical end near the triradiate ridge and results in formation of 2-3 layers thick tissue. This tissue region is called cushion and it becomes separated from the lower non-cellular region by formation of a diaphragm. The lower region is coenocytic and rich in starch. It becomes cellular after the embryo begins to develop. It provides food to the developing embryo therefore acts as endosperm.

The apical region of the spore wall cracks open to expose the cushion. The cells develop chloroplast and the tissue becomes photosynthetic. At this stage the female gametophyte fals on the ground, and develop rhizoids. The neck projects above the level of gametophyte.

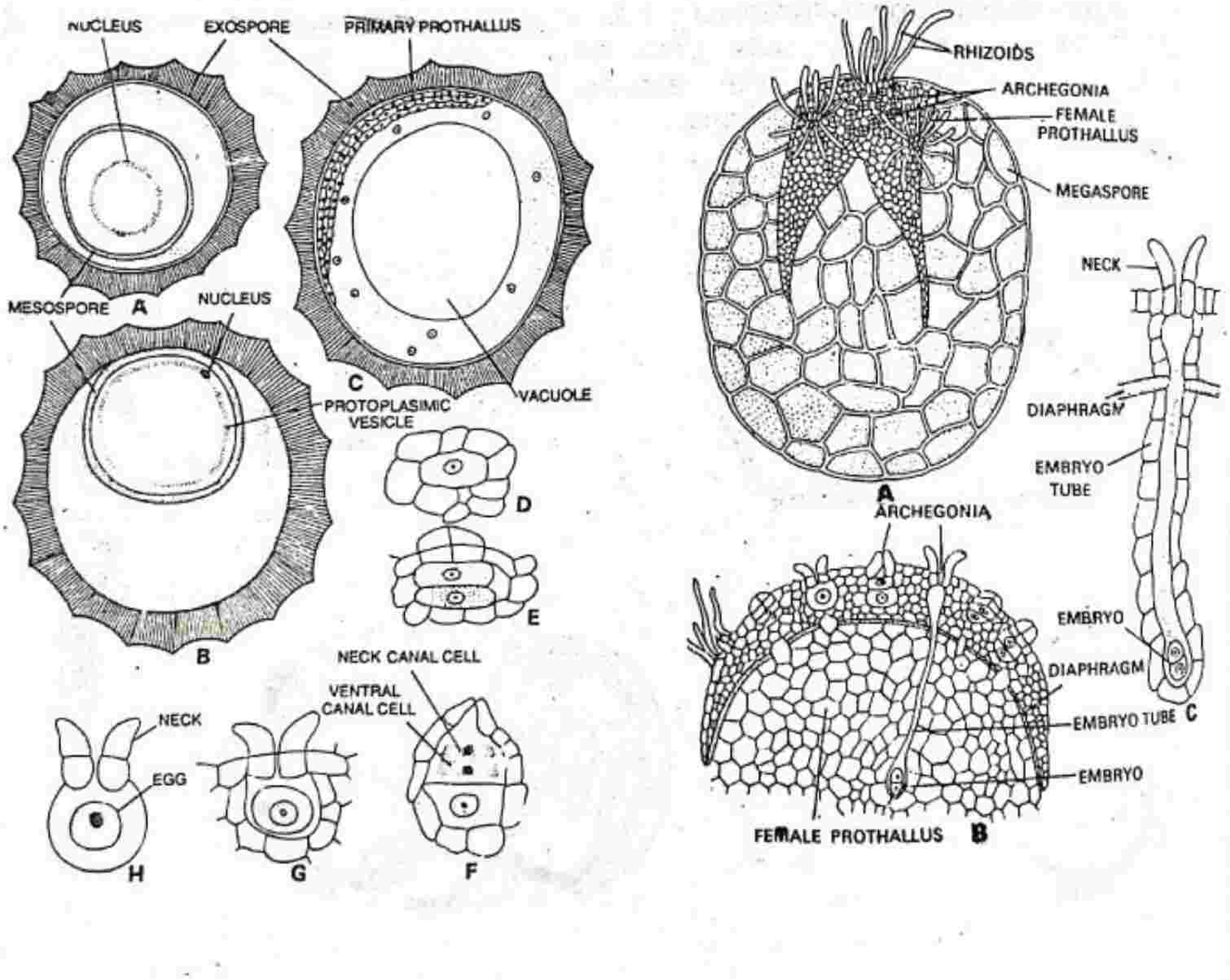

Fig. 7.25: Selaginella — A. Successive stages in the development of female gametophyte and archegonia; B. Detailed structure of female gametophyte.

Structure and Development of Archegonia

The archegonia develop in center of the cushion. Each archegonium consists of neck composed of eight cells arranged in two tiers of four cells each; and basal swollen part, the venter. The neck contains a neck canal cell whereas a venter canal cell and an egg cell is present in the venter.

Archegonium develops from a single superficial cell which divides into a primary cover cell and a central cell. The cover cell divides by two anticlinal divisions at right angles to each other to give rise to four neck initials. Each neck initial divides by a transverse division to form neck two tiers in height, each composed of four rows of cells. The central cell divides periclinally to form primary canal cell which functions as neck canal cell, and primary venter cell which divide to form venter canal cell and egg cell.

Fertilization

In most species fertilization takes place when the female gametophyte is shed. The sperms swim to the archegonia in dew or rainwater. The neck canal cell and venter canal cell disintegrate and the neck cells separate to leave a passage for the entry of sperms. The sperms enter archegonium, reach the egg cell and one of these fuse with it to form the zygote.

Embryo Development

The first division of zygote is transverse and gives rise to a suspensor cell near the neck and an embryo cell. The suspensor cell elongates and pushes suspensor which pushes the developing embryo into the food-filled tissue of the gametophyte. The embryo cell divides by two vertical divisions to produce four cells. One of these four cells divides by a diagonal vertical division to form apical cell of the future stem. The apical cell cuts off a sister cell which alongwith the three remaining cells divide repeatedly. The cells of cells near the suspensor differentiate into foot. The foot is haustorial and absorbs food from the gametophyte. At the same time apical cells of the cotyledons are differentiated in upper tiers which give rise to embryonal leaves. The apical cell the stem divides and produce shoot apex. An apical cell separates from one flank of the foot and cuts off segments which form rhizopore.

The developing embryo grows through the gametophyte tissue. The stem and cotyledons grow upward and rhizophore grows downward to establish the sporophyte.

Apogamy and Parthenogenesis

It has been found that embryos may develop by apogamy from archegonial initials in some *Selaginella* spp. However it is not much common.

Parthenogenesis is more profound in *Selaginella*. The unfertilized eggs develop into new plants parthenogenetically in several species. In some of these species only megasporangia are present in the strobili. In others the strobili contains both types of sporangia but the archegonial neck remains closed and male sperms cannot enter to fertilize. In still others the only megaspores are viable while the microspores are abort.

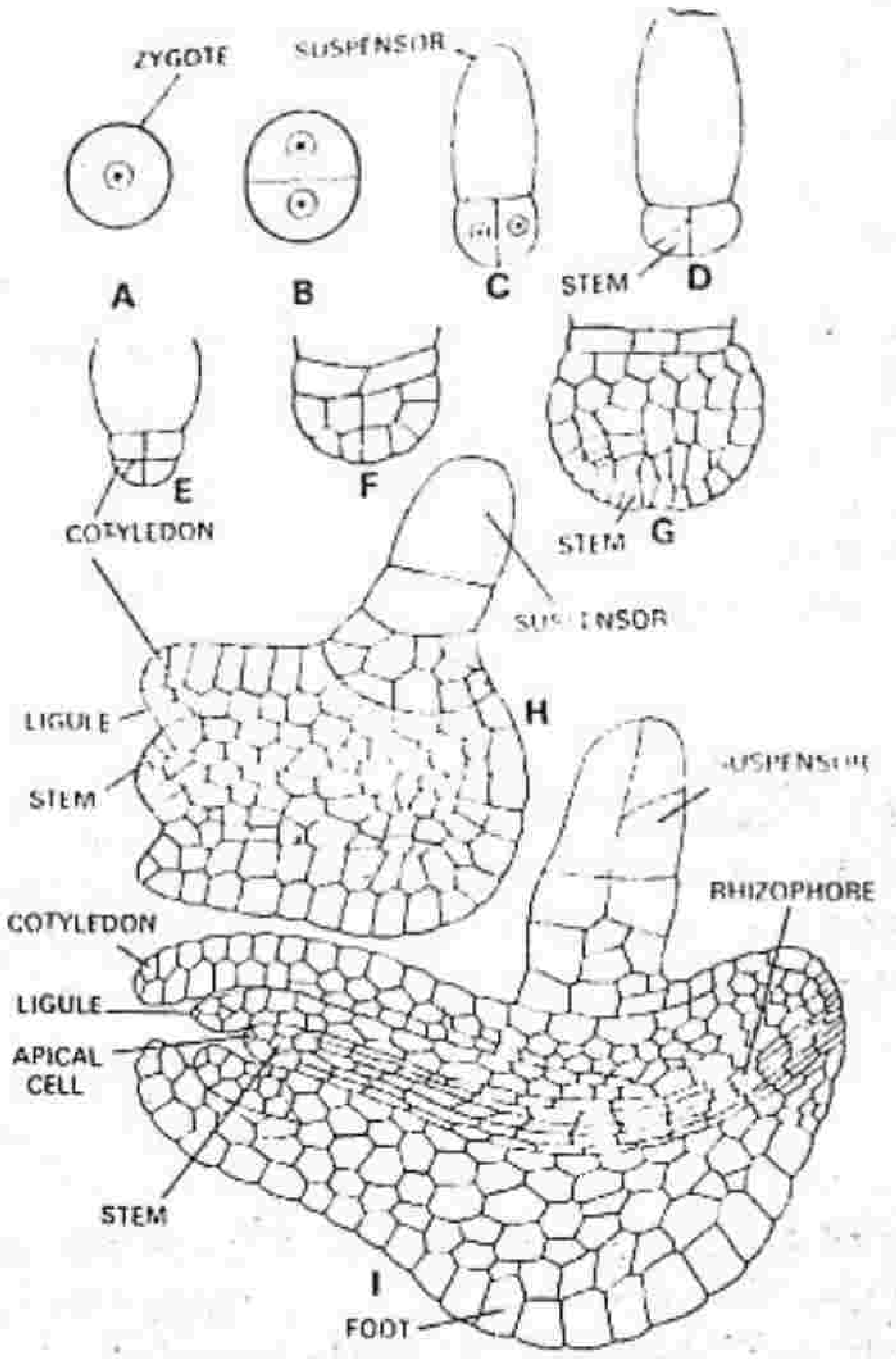

Fig. 7.26: Selaginella — Development of embryo.

HETEROSPORY —A STEP TOWARDS SEED FORMATION

Heterospory

Production of two types of spore. The microspore in microsporangia and mega spore in megasporangia is called as heterospory.

IMPORTANCE OF HETEROSPORY

There are two important aspects of heterospory:

i.An Expression of Sex Determination

Heterospory is an expression of sex determination. In homosporous species, the sex determinants exert their affect in gametophyte whereas in heterosporous species the sex determinants exert their influence during spore formation. For example, in Equisetum (homosporous) the gametophytes are alike and these differentiate into male and female gametophytes during later stages of development, but in Selaginella (heterosporous) the microspores develop into male and megaspores into female gametophytes always.

ii.A Step Towards Seed Habit.

Heterospory is considered a pre-requisite for seed formation. It led to changes vital for seed habit such as reduction in number of megaspores, reduction in megasporangium and female gametophyte on sporophyte, origin of pollination, etc. These changes gradually resulted in development of a seed.

Origin of Heterospory

There is an evidence of heterospory from fossil studies. The fossil record suggests presence of widespread occurrence of heterospory in all major plant groups. A number of heterosporous genera are reported from late Devonian and early Carboniferous periods. They belong to Lycopsida, Sphenopsida and Pteropsida. In some of these, the heterospory is pronounced whereas in others it is not.

The fossil studies revealed that abortion of spores led to development of spores of different sizes. However, there was no evidence that these spores developed into different gametophytes. The developmental and comparative studies in living heterosporous genera, such as *Selaginella*, *Marselia*, *Azolla*, etc, threw more light on heterospory. The development of sporangia is same upto the formation of spore mother cells. Later, abortion of spore mother cells lead to development of megaspores which produce female gametophytes upon germination.

Heterospory and Seed Habit

All seed plants are heterosporous, therefore heterospory is considered as pre-requisite for seed formation. In addition the seed plants exhibit the following characteristics which may have helped in seed formation.

i. There is a single functional megaspore.

ii. The megasporangium is protected by protective coats, the integuments.

iii. The megasporangium is retained on the sporophyte and the female gametophyte is retained within the megasporangium.

iv. The nucellus (megasporagium) and megaspore wall is fused histologically.

v. Pollination, fertilization and development of embryo takes place within the wall of the female gametophyte and megasporangium.

vi. There is a reduction in the size of male gametophyte.

Selaginella and Seed Habit

Selaginella is the first living vascular cryptogam to exhibit heterospory. It exhibits following characteristics that resemble seed plants.

i. There is reduction in number of megaspores. In *Selaginella kraussiana* it is four, however in *Selaginella monospora* it is one.

ii. The megaspore starts its germination within the megasporangium and the release of female gametophyte differ with species.

iii. In *Selaginella rupestris*, the megaspore is retained on the sporophyte and fertilization and development of embryo takes place within it. This can be compared to viviparity in angiosperms.

iv. The megasporangium of Selaginella is comparable to nucellus of Pinus and food tissue in Selaginella is comparable to endosperm of Pinus which is continuation of female gametophyte. The sporangial wall in Selaginella is two-layered and it thickens and becomes strong at maturity.

v. In both Selaginella and Pinus archegonia develop in the female gametophyte with eggs in venter.

Why Selaginella Failed to form Seeds?

Despite of above mentioned characteristics in Selaginella that support seed formation, the genus failed to form seeds, because:

i. The protective structure, the integuments, are absent although the megasporangium in Selaginella is comparable to that of Pinus.

ii. The megaspore is not permanently retained in the megasporangium. The retention is reported in *Selaginella rupestris*, but the histological fusion of megaspore and megasporangium wall is absent which is necessary for permanent retention of the megaspore.

iii. There is lack of resting period after the development of embryo.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are lycopsida.
2. What is spike moss.
3. Which type of stele is found in Selaginella.
4. Give vegetative morphology of Selaginella.
5. What is spike.
6. Draw gametophyte of Selaginella.
7. What are microphyllus in Selaginella.
8. What is structure of archegonia.
9. Define heterospory.
10. What is importance of heterospory.
11. Why selaginella fail to form seed.

Long Questions

1. Describe gametophyte of Selaginella.
2. Describe internal structure of stem of Selaginella.
3. Describe life history of Selaginella.
4. Write note of development of sporangia.
5. Define heterospory. Explain it with Selaginella.
6. Describe gametophyte of Selaginella.
7. Why Selaginella fail to form seed.

ARTHROPHYTA (SPHENOPSIDA)

The division includes a group of vascular cryptogams known from Devonian strata. The plants were abundant during the Paleozoic, but only one genus Equisetum has survived. The members are commonly called horsetails. The division is also known by the name Calamophyta.

GENERAL ACCOUNT

1. The Arthrophyta (sphenopsids) comprises a well-defined group of living and extinct plants. Fossil remains are first found in strata considered to be of Devonian age. During the Carboniferous the group attained almost worldwide distribution and diversity in form.
2. Both tree-like and herbaceous species were common during this period. However, by the end of Triassic only a few representatives remained, and they were relatively small, herbaceous forms.
3. Today only one genus, Equisetum is present.
4. The sphenopsids have sporophytes differentiated into stem, leaves and roots.
5. The stem is jointed and differentiated into distinct nodes and internodes. Also longitudinal ribs are present on the stem surface. These ribs extend throughout the length of the internode and in most cases the ribs of an internode alternate with those of above or below it.
6. There are two types of leaves: the primitive sphenopsids possess flattened, wedge-shaped leaves with a dichotomously branched venation; whereas the Equisetales have scale-like, single-veined leaves. The leaves are borne in whorls at nodes of stems and branches. The leaves and branches alternate with each other at nodes.
7. The roots are known only a few instances and appear to be adventitious.
8. The primary vascular tissue of a stem may be protostelic, but most frequently it is siphonostelic.
9. The internodal portions of the vascular cylinder are dissected by parallel perforations extending vertically throughout the entire internode.
10. Carinal canals are present at the inner face of each metaxylem group. These are formed due to disintegration of protoxylem elements.
11. The primitive sphenopsids exhibit secondary growth, however it is absent in Equisetum.
12. The sphenopsids are sporophytes and the fertile portion consists of sporangia bearing appendages, the sporangiophores. These are always borne on the terminal portion of certain branches.
13. The sporangiophores arrange themselves to form a compact terminal strobilus.
14. In primitive sphenopsids the sporangiophore is cylindrical, once or twice dichotomously branched, and each dichotomy ultimately recurve and terminate in a single sporangium.

15. In Equisetum, each sporangiophore is peltate and a whorl of rudimentary bracts is present below the sporangiophore forming annulus. The sporangia are borne on the undersurface of the head.

16. Most sphenopsids are homosporous, however some species exhibit heterospory.

17. The gametophytes of Equisetales are long-lived and cushion-like first but become lobed and irregular in shape later due to more active growth at one side. The sex organs lie between the lobes.

18. The zygote germinate to produce quadrant type of embryo.

EQUISETUM

Taxonomic Position

Division:	Sphenophyta
Class:	Calamopsida
Order:	Equisetales
Family:	*Equisetaceae*
Genus:	*Equisetum*

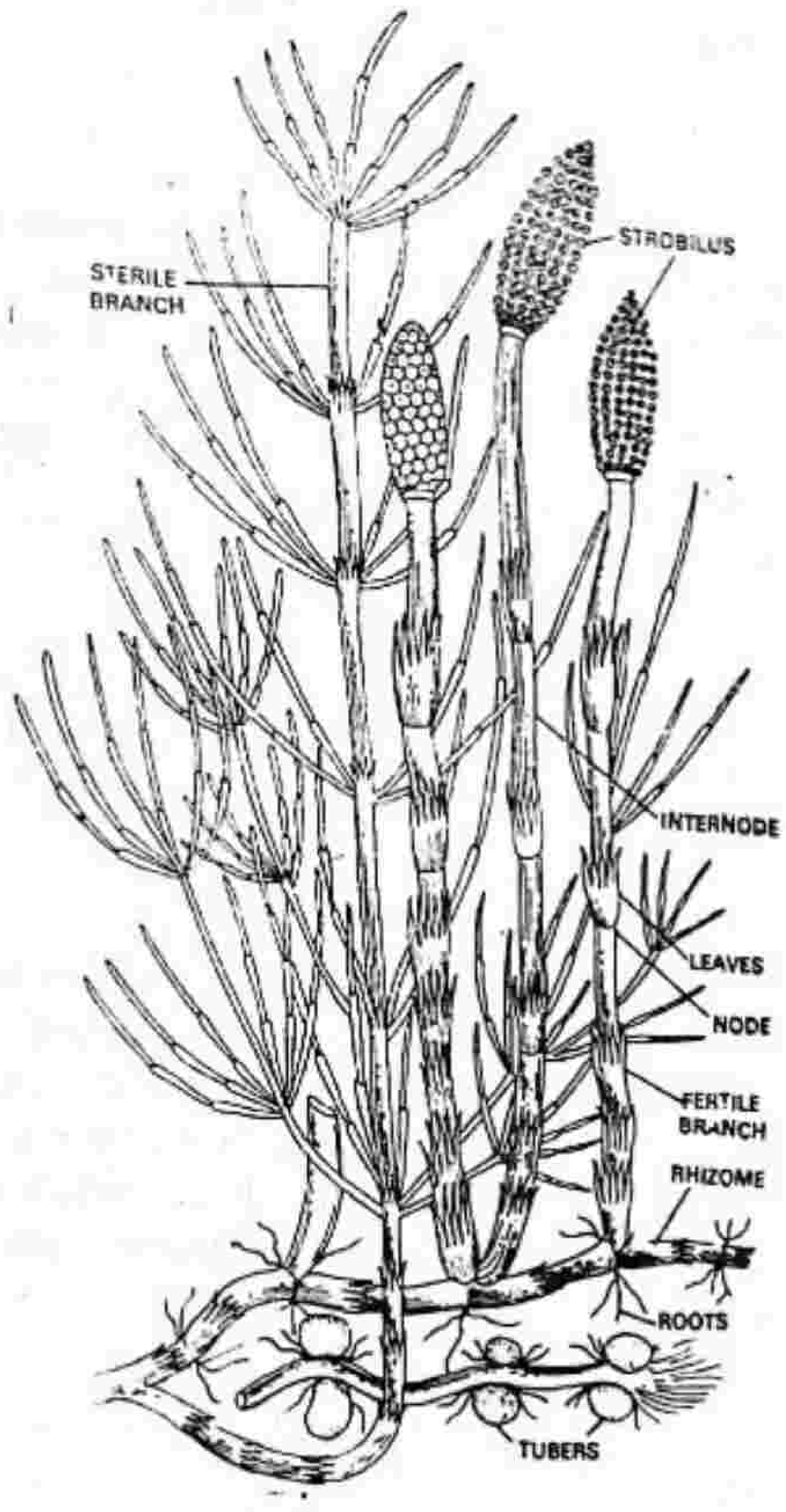

Fig. 7.27: Equisetum: A plant body.

Equisetum (L. Equus=horse + saeta=bristle) is the only living member of the family Equisetaceae. The species may be branched or unbranched. The branching species are called horsetails and unbranched species are known as pipes and scouring rushes commonly. Silica is a common constituent of cell walls of epidermal cells. It provides rough and abrasive touch to the stem.

Occurrence

The genus comprises of 25 species which are widely distributed in various habitats. However, these grow best in damp and shady places especially along the banks of streams. Some of these grow in marshy places only. The most common species of Indo-Pak region are *Equisetum debile, E. diffusum, E. arvense and E. ramosissimum.*

Vegetative Morphology

The plant is a sporophyte. The plant body consists of a horizontal, branched, underground, perennial rhizome which gives rise aerial branches.

Rhizome

Equisetum has perennial underground rhizome, which grows horizontally. It often penetrate deeply into the soil. It is well differentiated into node and internodes. At each node there is a whorl of small brown scale leaves which are united at their base forming a sheath. Lateral branches are arises from each node.

Aerial Branches

The aerial branches arise from the rhizome. They are green and attain the height of 2 feet. The branches are differentiated into node and internodes. The internodes have ridges and furrows. The ridges of adjacent internodes alternate with each other. There are whorl of small leaves are united at their bases forming well-developed sheath. The function of photosynthesis is mainly performed by aerial branch. The leaves are reduced and non-functional.

Root

Roots develop on rhizome. The first root is primary but it is short-lived. Later, adventitious roots arise from the bases of branch primordia present at the nodes of the rhizome. The roots anchor the plant and absorb water and minerals from the soil.

Apical Growth

Equisetum is favourable plant for investigation of apical meristems. Apical growth of rhizome and branches is initiated by a pyramidal apical cell with three cutting faces. The apical cell cuts off segments successively. Each segment divides anticlinally to form two cells which develop into a nodal and an internodal sector of the stem. Each of the two cells divides periclinally to form a smaller inner cell which contributes to the pith, and an larger outer cell which give rise to the other parts of the sector. The branch initials arise several nodes back from the apical cell.

INTERNAL ANATOMY

The Stem

In a transverse section the general outline of the stem is wavy due to presence of ridges (ribs) and grooves (in between the ribs).

The aerial branch of Equisetum under transverse section shows the following demarcations.

Epidermis

The outer surface of the stem is covered by a single layer of epidermis. The wall of epidermis is heavily slicified. Stomata are present in the epidermis, which are situated in the furrows between the ridges.

Cortex

The cortex of is divided into following parts

Sclerenchymatous cortex

There is large bands of sclerenchyma in the peripheral portion of the cortex just below the ridges.

Chlorenchmatous cortex

It is next to the seclerenchyma tissues and is formed by 2-5 layer of cells. The cells are thin walled and are parenchymatous. The cells contained chloroplast they are main photosynthetic tissues in the stem.

Parenchymatous cortex

They form the major portion of the stem. The cells are thin walled and having no inter cellular spaces in them.

Vallecular canal

These are long canals known as vallecular canals. They are present in the cortex just opposite to the groove.

Endodermis

There is well developed endodermis between the stele and the cortex. These cells have casparian bands on their radial walls.

Stele

Next to the endodermis is the steler region. It is siphonostele and the vascular bundles are arranged in a ring around a pith. Each bundle lies just opposite to each ridge. Each vascular bundle is collateral xylem is inner side while the phloem is outer side.

Pericycle

It is present just below the endodermis. It consists of a single layer of cells.

Xylem

Each vascular bundle is collateral and consists of xylem and phloem. The xylem is V shaped structure and protoxylem occupies the basal portion while the meta xylem on the tip of the arms. In the mature vascular bundle a cavity called as carinal canal is formed by the disintegration of xylem tissues.

Phloem

Between the endodermis and the xylem is the phloem. The phloem is composed of sieve tube and phloem parenchyma. Vessels have been reported in at least five species of Equisetum. Each vessel is composed of two vessel elements and their perforations are connected to the carinal canals.

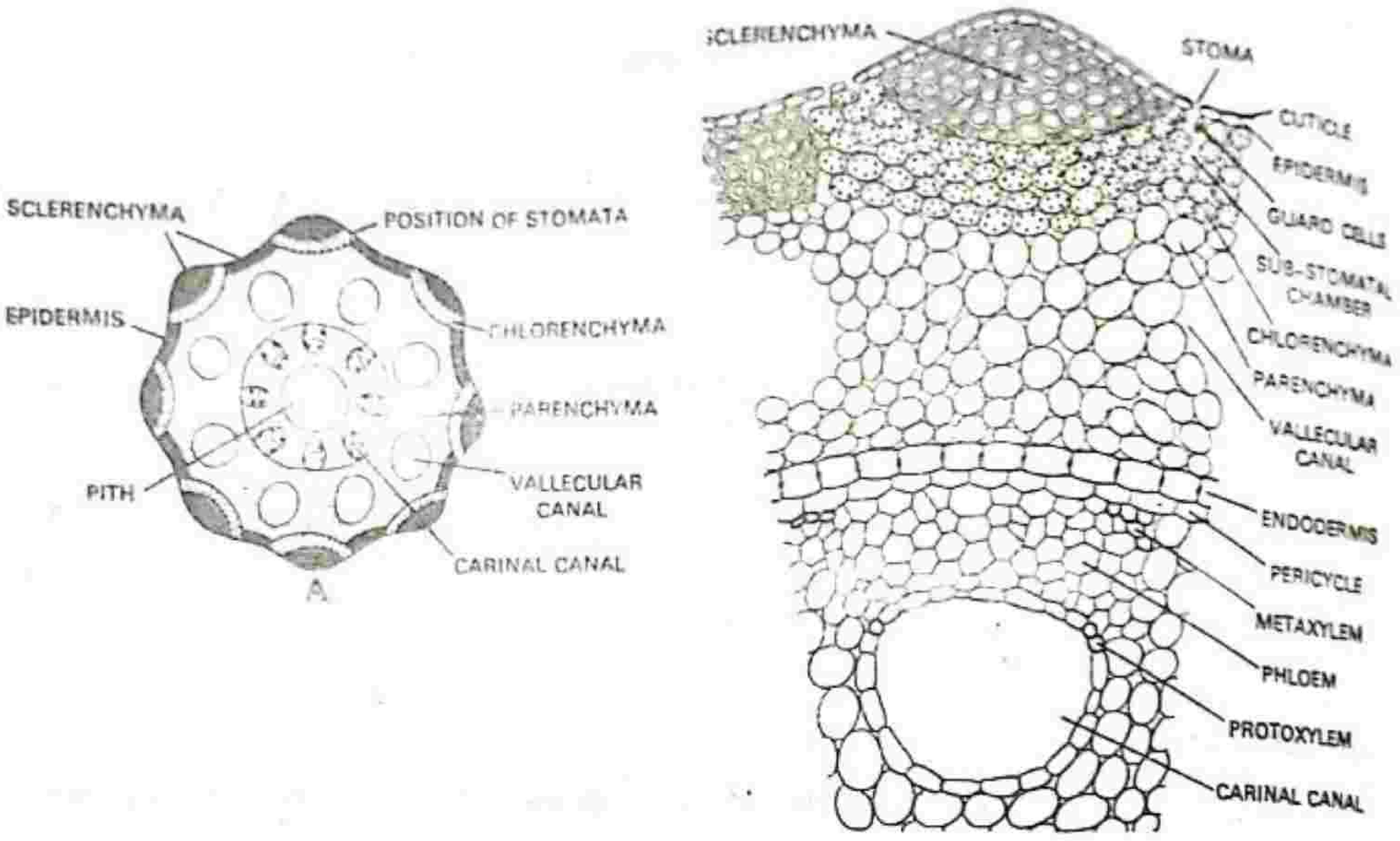

Fig. 7.28: Equisetum — Internal structure of stem.Canal System

Reproduction

Equisetum is homosporous lower vascular plant which reproduces by vegetative and asexual means of reproduction.

Vegetative Reproduction

In some species, e. g., *Equisetum arvense* new plants develop from tuberous branches that arise from rhizome. The branch primordia develop into short rounded branches one internode long which store food. Each branch develops into a new plant upon detachment from the parent rhizome.

Asexual Reproduction — Sporophyte

Asexual reproduction is by spores produced in sporangia borne on peltate structures, the sporangiophores, which are arranged upon a common axis to form a strobilus.

Strobili (Cone)

The strobili develop at the tips of ordinary vegetative shoots usually, however in some species, for example in *Equisetum arvense*the strobili are borne at the tips of non-green fertile branches.

Each strobilus consists of a main axis upon which a number of T-shaped peltate appendages called sporangiophores are arranged in whorls. Each sporangiophore has a stalk and a flattened, peltate free end called head. 5-10 sporangia develop in a ring on the underside of the head. The heads of sporangiophores fit closely together to provide protection to the sporangia during development. The heads of sporangiophores appear to be hexagonal because of mutual pressure of adjoining sporagiophores. A ring-like outgrowth called annulus is present immediately below the sporangiophores on the main axis. It is considered to be a vestigial bract. At maturity the cone axis and sporangiophores shrink to expose the sporangia.

Structure and Development of Sporangium

Each sporangium is elongate, finger-like with rounded apex. It consists of a mass of sporogenous tissue surrounded by a nutritive layer, the tapetum and a two-layered sporangium wall. The cells of the outer layer develop helical thickening.

Each sporangium initiates from a single superficial cell around the rim of the sporangiophore. It divides by a periclinal division into an inner and an outer cell. The inner cell divides repeatedly to form sporogenous tissue. The outer cell divides by anticlinal and periclinal divisions to give rise to irregular tiers of cells. The inner tiers of cells add to the sporogenous tissue, whereas the outer tiers differentiate into a part of many-layered sporangium wall. The rest of the wall is contributed by cells adjacent to the original initial. The innermost wall layer functions as a tapetum. During spore development, the tapetal layer and all except two wall layers disintegrate to form plasmodial fluid which provides nutrition to the developing spores. Therefore, the wall is two layered in a mature sporangium. The sporogenous cells undergo repeated divisions and the last generation of cells is spore mother cells. About one-third spore mother cells disintegrate and the remaining undergo meiosis to produce tetrads of spores.

Each spore is unicellular, uninucleate, and its protoplast is surrounded by a spore wall consisting of four concentric layers. Mature spores contain chloroplasts.

Elaters

The outermost spore wall layer consists of four spiral strips. These four strips split away from the remainder of the wall except for one common point of attachment. These strips remain tightly coiled about the spore until the sporangium wall splits open. The strips are hygroscopic and called elaters. They coil or uncoil accordingly as the air is moist or dry.

Dehiscence of Strobilus and Dispersal of Spores

When the spores are ready for dispersal, the internodes of the strobilus elongate slightly thus separating the sporangiophores. The stalk of each sporangiophore increases in length so the sporangia are exposed. The sporangium wall splits open by formation of a longitudinal slit in part of sporangial wall near the sporangiophore stalk. The spores fall on the ground and remain viable for few days.

Sexual Reproduction — Gametophyte

The gametophyte in Equisetum is reduced, therefore a prothallus. They are generally found growing on clayey soil and in the mud belt along the banks of streams.

Structure and Development of Gametophyte

The spore cell divides by an unequal division into a small lens-shaped rhizoidal cell which elongates to form a rhizoid, and a large prothalial cell which divides to form a circular or irregular, dorsiventral, parenchymatous, cushion-like body. The cells of the

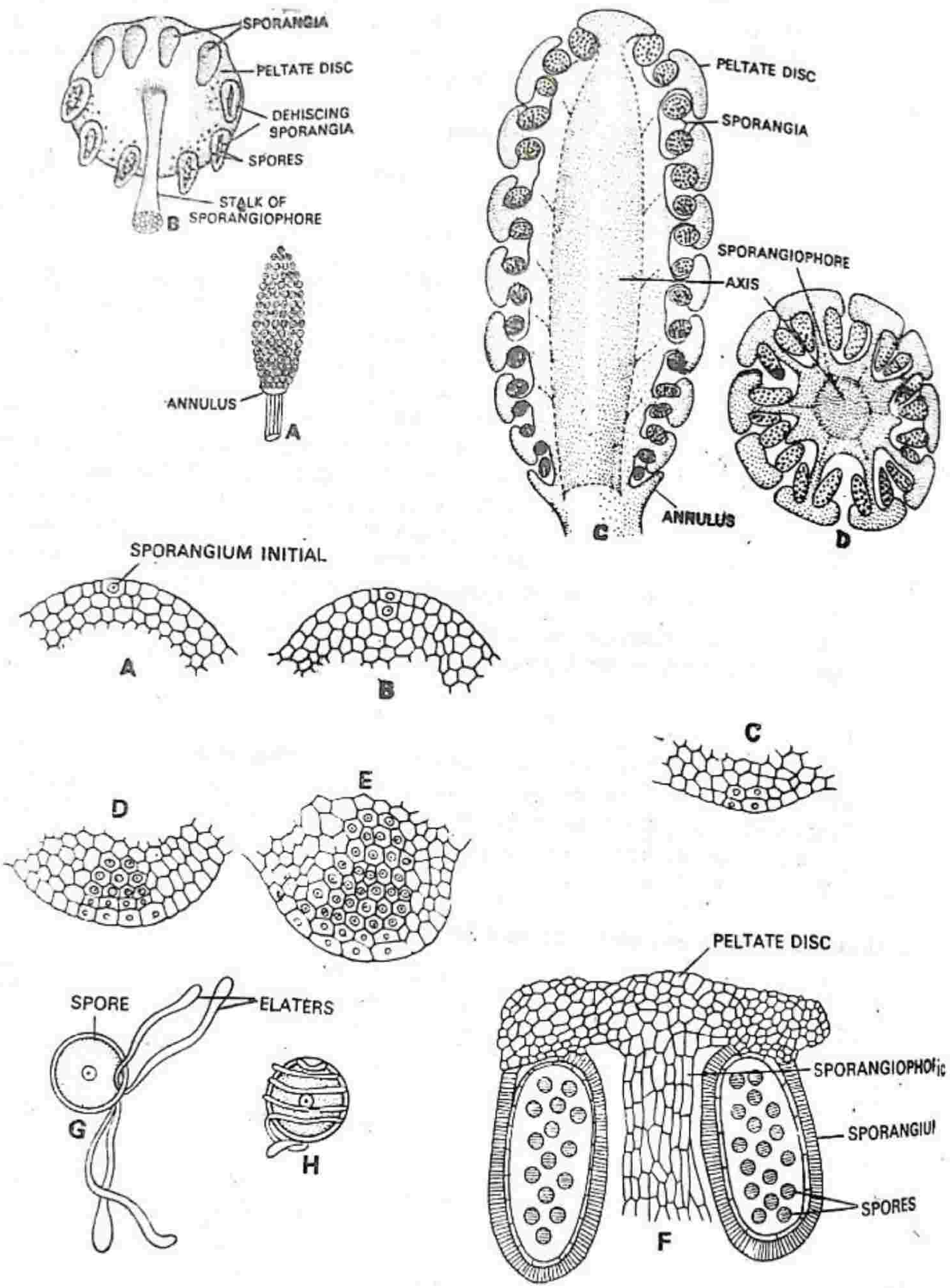

Fig. 7.29: Equisetum — A. Strobilus morpholgy and internal structure; B. Successive stages in development of sporangia.

upper part of prothallus contain chloroplasts whereas the cells of the lower part are colourless. The entire margin of the prothallus is meristematic. Irregularly-shaped green aerial lobes arise from the upper portion of the prothallus.

Sex Organs

There has been considerable debate regarding the homomthallic or heterothallic nature of Equisetum, but reports indicate that gametophytes are homothallic.

Structure and Development of Archegonium

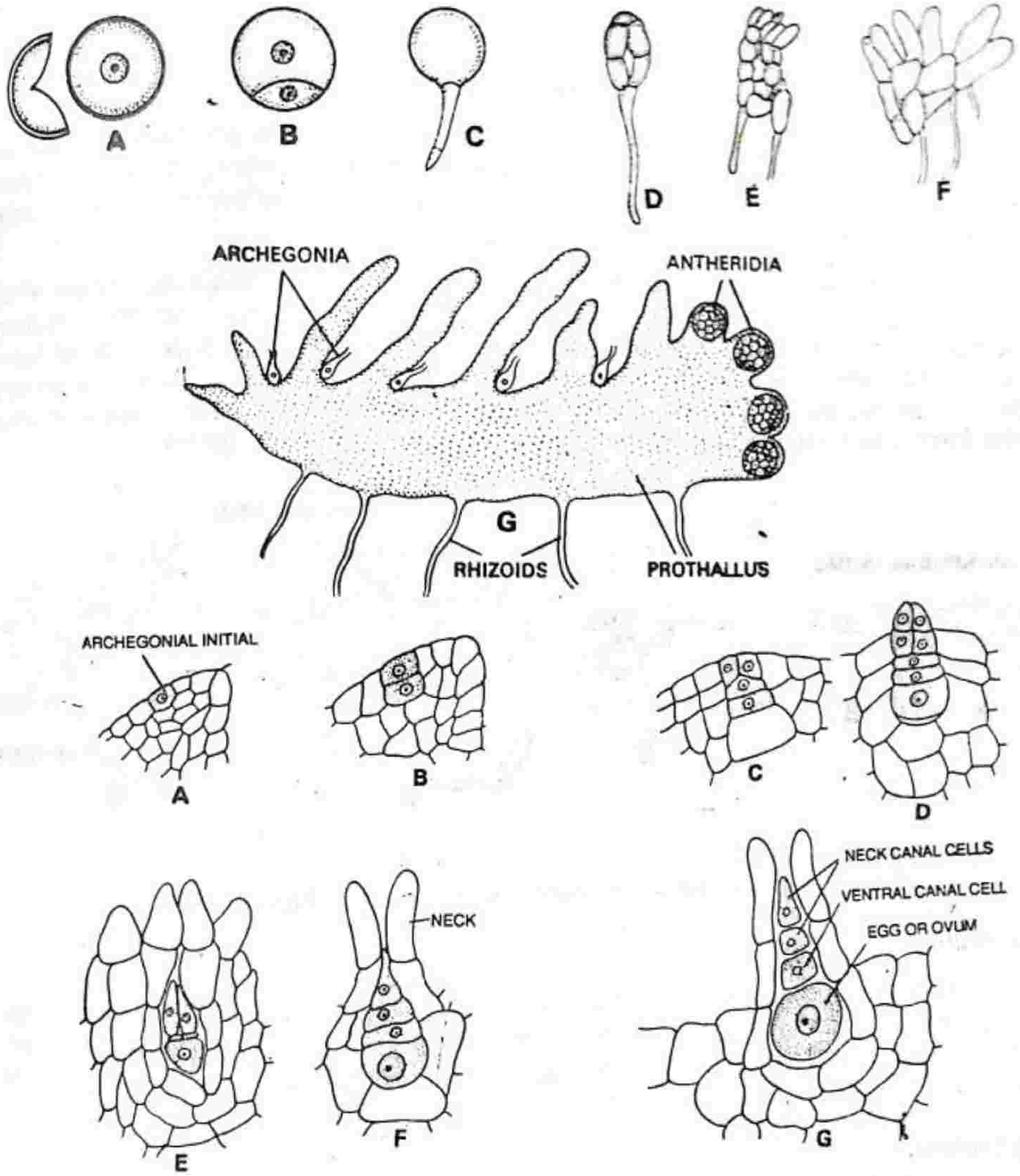

Fig. 7.30: Equisetum — A. Structure and development of gametophyte; B. Structure and development of archegonium.

The archegonia develop in the tissue between aerial lobes on the prostrate portion of the gametophyte. A mature archegonium consists of basal portion, the venter embedded in the prothallus tissue;neck composed of two to three tiers of cells arranged in four rows. An axial row of two boot-shaped neck canal cells, a venter canal cell and egg cell is present in the archegonium.

Each archegonium develops from a single superficial cell which divides by a periclinal division into an outer primary cover cell which divides to form four primary neck cells, and an inner central cell. The neck cells divide transversely to produce neck three to four cells high. The central cell divides transversely into a primary canal cell which divides vertically into two boot-shaped neck canal cells, and primary venter cell that divides unequally into a smaller venter canal cell and an egg cell. All these cells except egg cell disintegrate.

Structure and Development of Antheridium

The antheridia may develop on the prostrate part of the prothallus (embedded type) or at the apices or margins of the aerial lobes (projecting type). A mature antheridium consists of a single layer of two to four jacket cells which enclose a large number of spermatogenous cells.

The antheridium develops from a superficial cell of meristematic region which divides by a periclinal wall to give rise to an outer jacket initial and inner primary spermatogenous cell. The jacket initial divides anticlinally and to produce a jacket layer, one cell in thickness. A triangular opercular cell is present in the jacket layer. The primary spermatogenous cell divides repeatedly and the last generation of cells is sperm mother cells. Each sperm mother cell metamorphoses into a multiflagellate sperm.

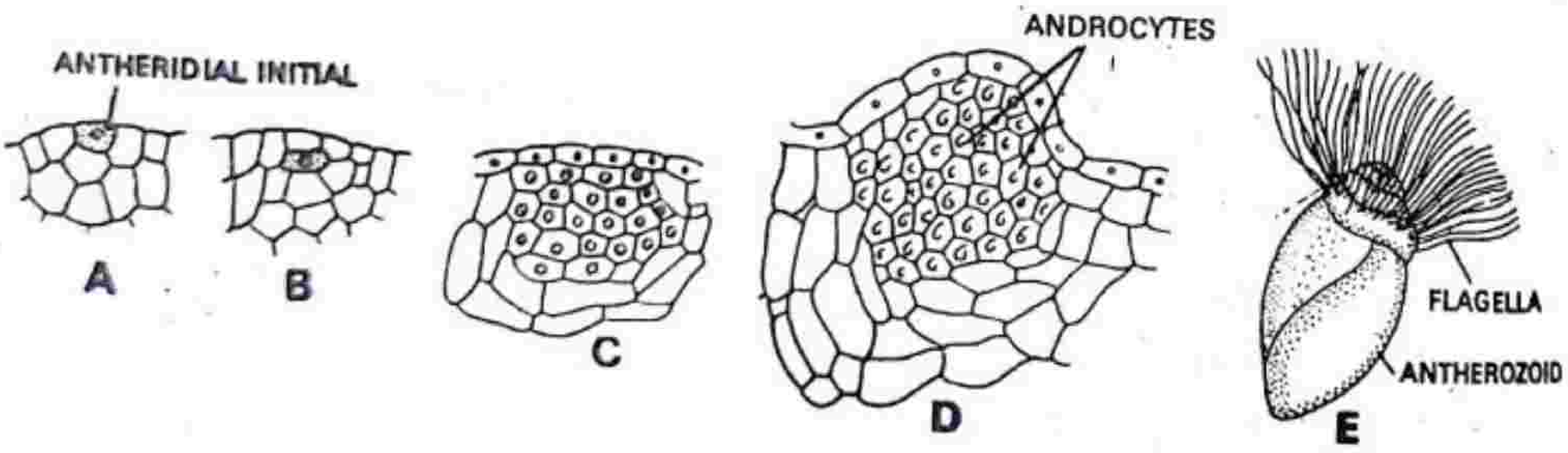

Fig. 7.31: Equisetum — Structure and development of antheridium.

Fertilization

Fertilization requires water. The thalli become covered with water which causes disintegration of opercular cell in the jacket layer. The male sperms move out and swim to the archegonium. Many enter the archegonium but only one succeeds in fertilizing the egg to form the zygote.

The Embryo

The zygote divides first by a transverse wall and then by a division at right angles to the first one to form a quadrant. The cells of hypobasal region are smaller and give rise to foot and root, and the cells of epibasal region are larger and produce embryonic shoot (*E. arvense*). During early phases of development, an apical cell of the stem is differentiated in the epibasal region. The cells lateral to it develop into the first leaf sheath of the young stem which contains varying number of small, scale-like leaves. Similarly an apical cell of the root differentiate which give rise to embryonal root. The root grows downward through the gametophyte tissue into the soil. The stem burst out of the embryo through the neck of the archegonium and grows upright. It becomes differentiated into nodes and internodes and bears a whorl of leaves at each node. A new branch arise from the base of the primary branch. Later many more new branches arise. One of these branches bend downward, grow into the soil and develops into a rhizome.

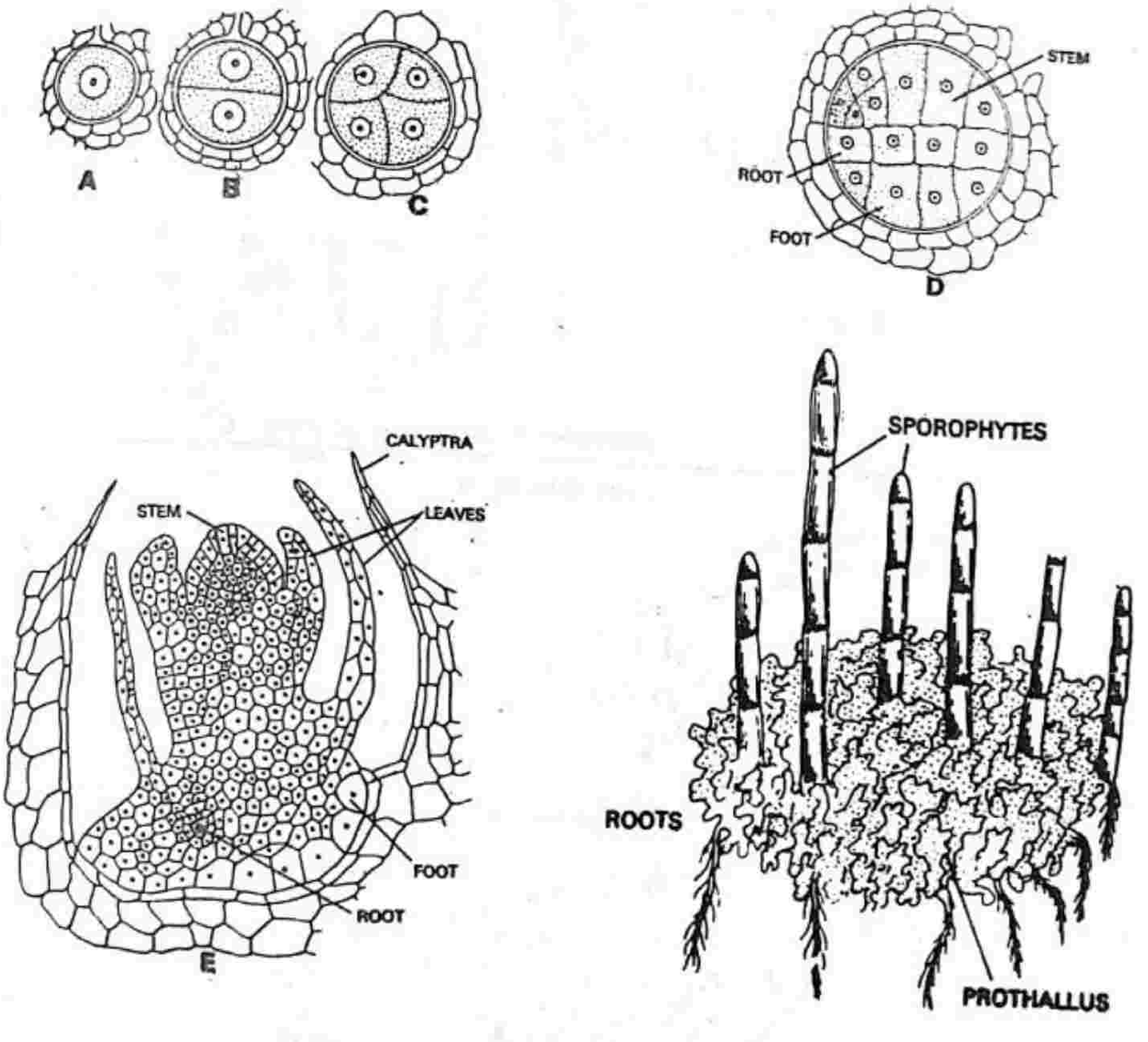

Fig. 7.32: Equisetum — Development of sporophyte.

Economic Importance

The genus Equisetum exhibits the following economically important features:

i. The presence of silica in the stem gives a rough and abrasive touch and bundles of stems are used to clean utensils and for polishing wood.

ii. Some species are of great medicinal value. The plant of Equisetum arvense is used as a diuretic in Germany. The ashes of this plants are also used to relieve acidity and dyspepsia. It also yields silica in therapeutically active form.

iii. Benedict reported the presence of gold ($4^1/_2$ oz per ton) in some species.

iv. Some species are used as indicators of mineral contents in the soil.

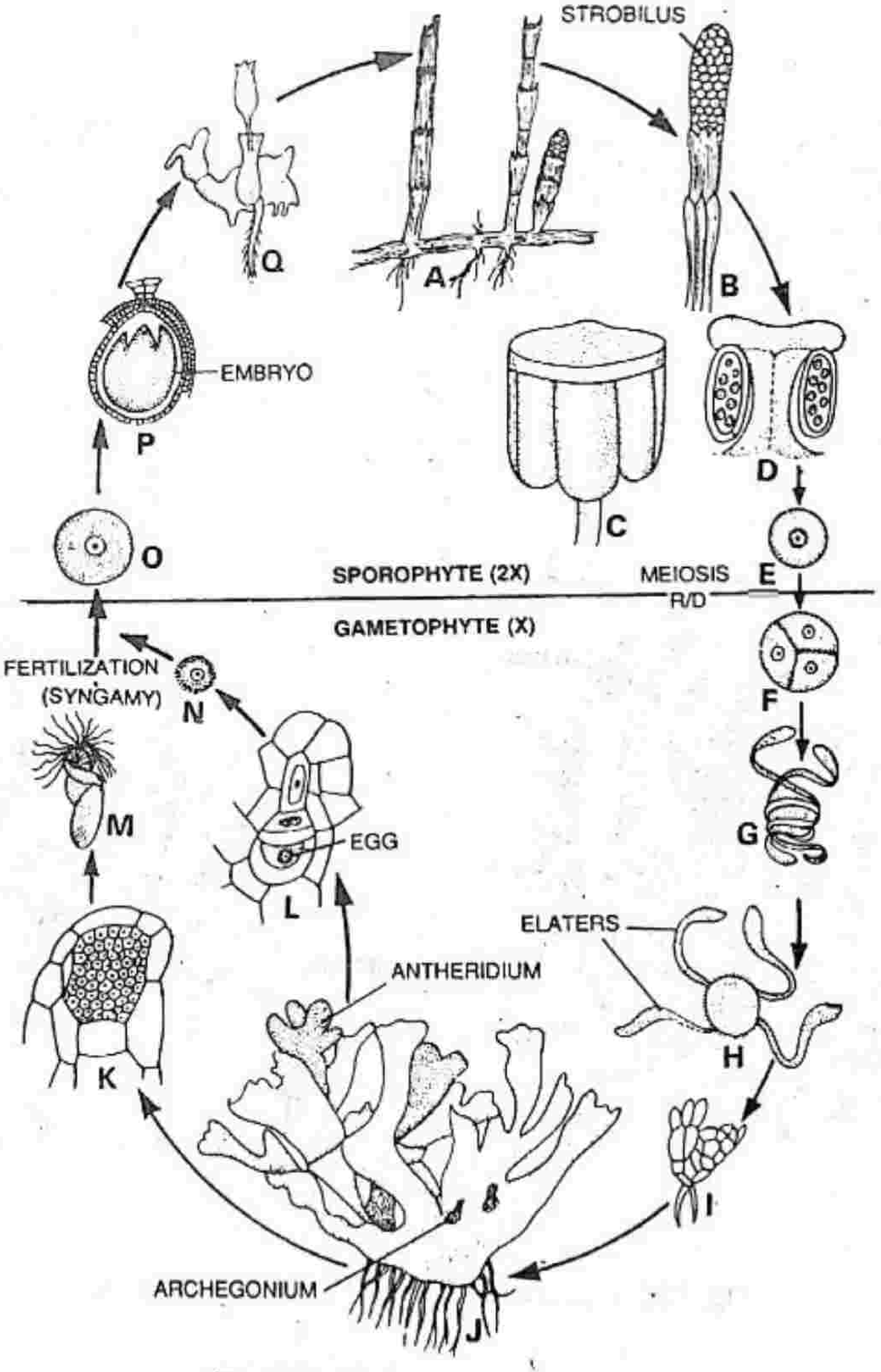

Fig. 7.33: Equisetum — Life cycle.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are arthrophyta.
2. What is horse tail.
3. Which type of stele is found in Equisetum.
4. Which type of rhizome is found in Equisetum.
5. Draw cone of Equisetum.
6. Draw gametophyte of Equisetum.
7. Is gametophyte of Equisetum is photosynthetic.
8. What are vallecular canal.
9. What are economic importance of Equisetum.
10. Draw diagram of gametophyte of Equisetum.

B. Long Questions

1. Write a note on cone of Equisetum.
2. Describe internal structure of stem of Equisetum.
3. Describe life history of Equisetum.
4. Write note of development of gametophyte.
5. Describe sexual reproduction in Equisetum.

PTEROPSIDA

The Pteriodophyta (pteropsids) are broadly termed ferns. It is an assemblage of vascular cryptogams that have established themselves most successfully to life on land.

GENERAL ACCOUNT OF PTEROPSIDA

1. The ferns are found in varied habitats and their ability to propagate vegetatively help them to compete with seed plants.
2. There are about 305 living genera and 10,000 species present throughout the world.
3. Some species are restricted to specific areas while the others are worldwide in distribution in the tropic and temperate zones. The ferns are quite numerous and are most diverse in the tropics and temperate rain forests. Many of them becoming trees 20-40 feet high or growing as epiphytes.
4. The ferns are well known from the fossil record as far as back as the Devonian. The true ferns are found in Permian and the present day survivors evolved during Triassic and Jurassic.
5. The pteropsids have a sporophyte differentiated into stem, leaves and roots.
6. The stem may be a creeping rhizome, or grow above the soil into columnar aerial stem. The branching may be dichotomous (*Dryopteris, Polypodium, Pteridium*) or lateral (*Adiantum*).
7. The leaves are megaphyllous and commonly called a frond. It is usually differentiated into a petiole and a dissected blade with a central axis, the rachis. The frond is usually a compound pinnnate leaf, may be once pinnate, bipinnate or tripinnate. The leaf blade is divided into smaller units, the pinnae attached to the rachis. The leaf usually has a branched venation system. The leaves are photosynthetic as well as reproductive as they bear sporangia.
8. The roots usually arise from the lower part of an aerial stem or from the lower surface of a rhizome.
9. The vascular cylinder of the stem ranges from simple dissected protostele, or a siphonostele or a dictyostele to a polycyclic condition. The xylem lacks vessels except in *Pteridium and Marselia* spp.
10. The ferns reproduce vegetatively by various methods and this type of reproduction helped them to colonize different habitats alongwith seed plants.
11. Asexual reproduction is by spore formation.
12. Most species are homosporous, but a few like *Marselia* are heterosporous.
13. The spores are produced in sporangia. The sporangia develop either on the margins or the abaxial face of the leaf blade in distinct groups known as sori. The sporangia in most cases possess a distinct annulus (the mechanism causing dehiscence) and a stomium.
14. The gametophytes are free-living, independent plants which are either photosynthetic or mycorrhizal. They may be plate-like, filamentous or cushion-like (Adiantum).
15. The gametophytes may be exosporic or endosporic and are usually monoecious in homosporous types.
16. The sex organs are usually embedded in the gametophyte tissue. However, in advanced species the antheridia are emergent.

ADIANTUM

Taxonomic Position

Division:	Filicophyta
Class:	Leptosporangiopsida
Order:	Filicales
Family:	*Polypodiaceae*
Genus:	*Adiantum*

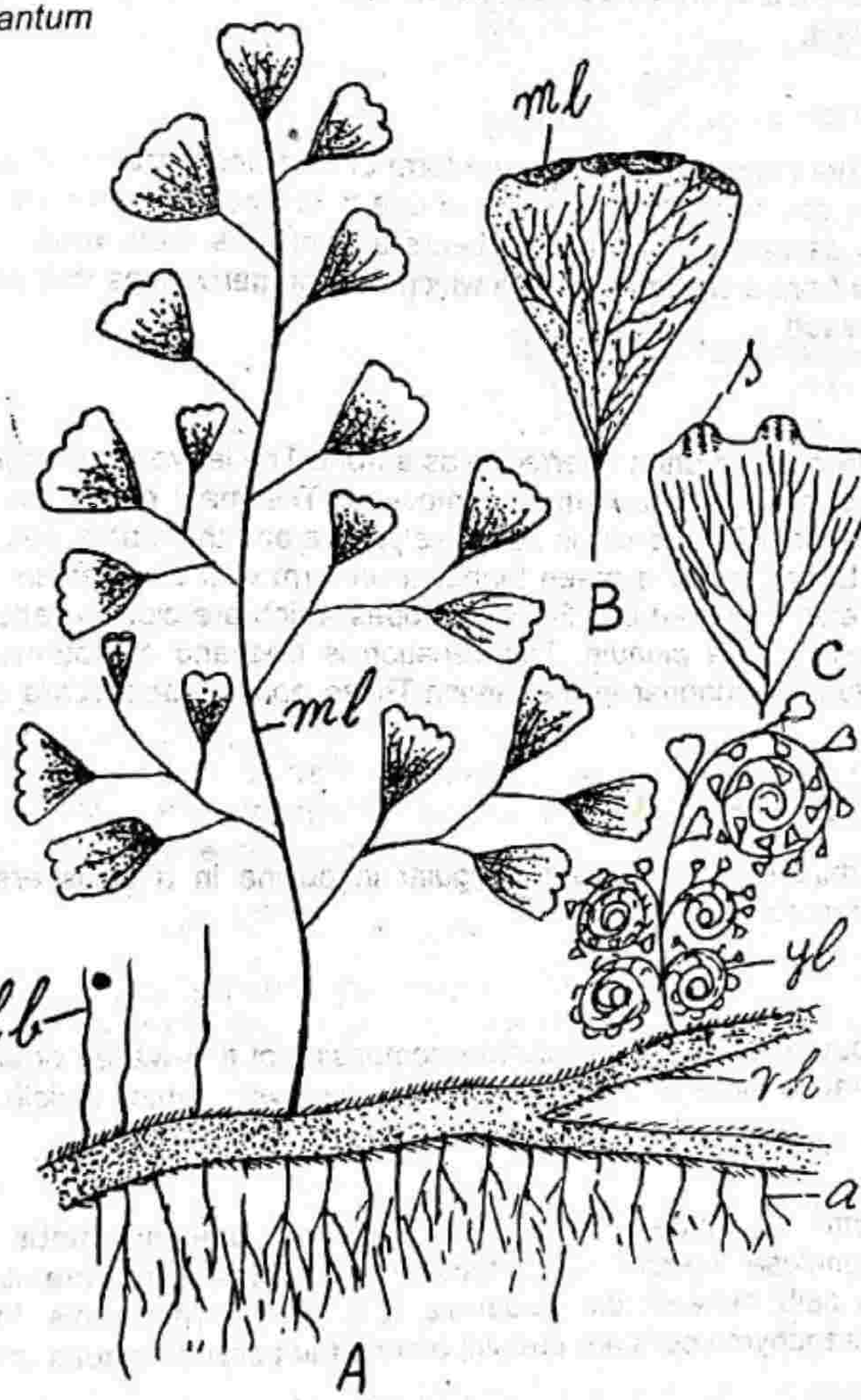

Fig. 7.34: Adiantum: Plant Body.

Occurrence

Adiantum is a widespread fern which grows in mild climates. It prefers to grow in moist and shady habitats. *Adiantum* spp are common in plains and hilly tracts of Pakistan. These are also grown for ornamental purposes. The petioles of the leaves are shining black and brittle. Due to this characteristic the *Adiantum* is also called maiden hair fern.

Vegetative Morphology

The plant is a homosporous sporophyte and plant body is differentiated into root, stem and leaves.

Rhizome

The stem is underground in the form of creeping rhizome. It grows very near the surface of the soil. It attains the height of one to six inches. It is covered with numerous scales called as palea. The rhizome bears adventitious roots which may be branched. They develop from a single apical cell which cuts off derivatives that develop into various cells of root tissue.

Leaves

The fern leaf is often referred to as a frond.The leaves are large about 4-6 inches in length. The leaves are bipinntely compound. The main axis of the leaf is called as rachis. The leaf let of first order is called as pinnae and the leaf of second order is called as pinnules. Each leaf let is green triangular in form with broader end toward the apex. The broader end is divided into 3-4 small lobes which are closely reflexed back towards the ventral side of the pinnule. The venation is free and dichotomous and the veins spread in a fan-like manner in the lamina.These apical lobes bears sporangia on their under side.

ANATOMY OF RHIZOME

The rhizome is wavy and irregular in outline in a transverse section. It has following demarcations.

Epidermis

The outermost layer is epidermis comprising of thin-walled or slightly thick-walled cells. It external surfaces of epidermal cells are lined with a thick cuticle.

Cortex

Beneath the epidermis there is a zone of parenchymatous cells, the cortex. These cells enclose intercellular spaces. In some species there is distinct layer of sclerenchyma cells beneath the epidermis. It is called hypodermis. In others scattered groups of sclerenchyma cells are present among the parenchymtous cortex.

Stelar Organization

The stele is protostele in embryonic stem, but in older stems it gradually changes into siphonostele, solenostele or dictyostele depending upon species. It is completely surrounded by a well differentiated endodermis that separates it from pith and cortex. The xylem is mesarch in development and composed chiefly of elongate tracheids. The pit osing membranes of end walls of tracheids dissolve at maturity resulting in direct ontinuity between adjacent elements. These elements are referred to as primitive essels. The phloem is composed of sieve elements. These are elongate and have umerous sieve areas in their vertical walls. Companion cells are absent.

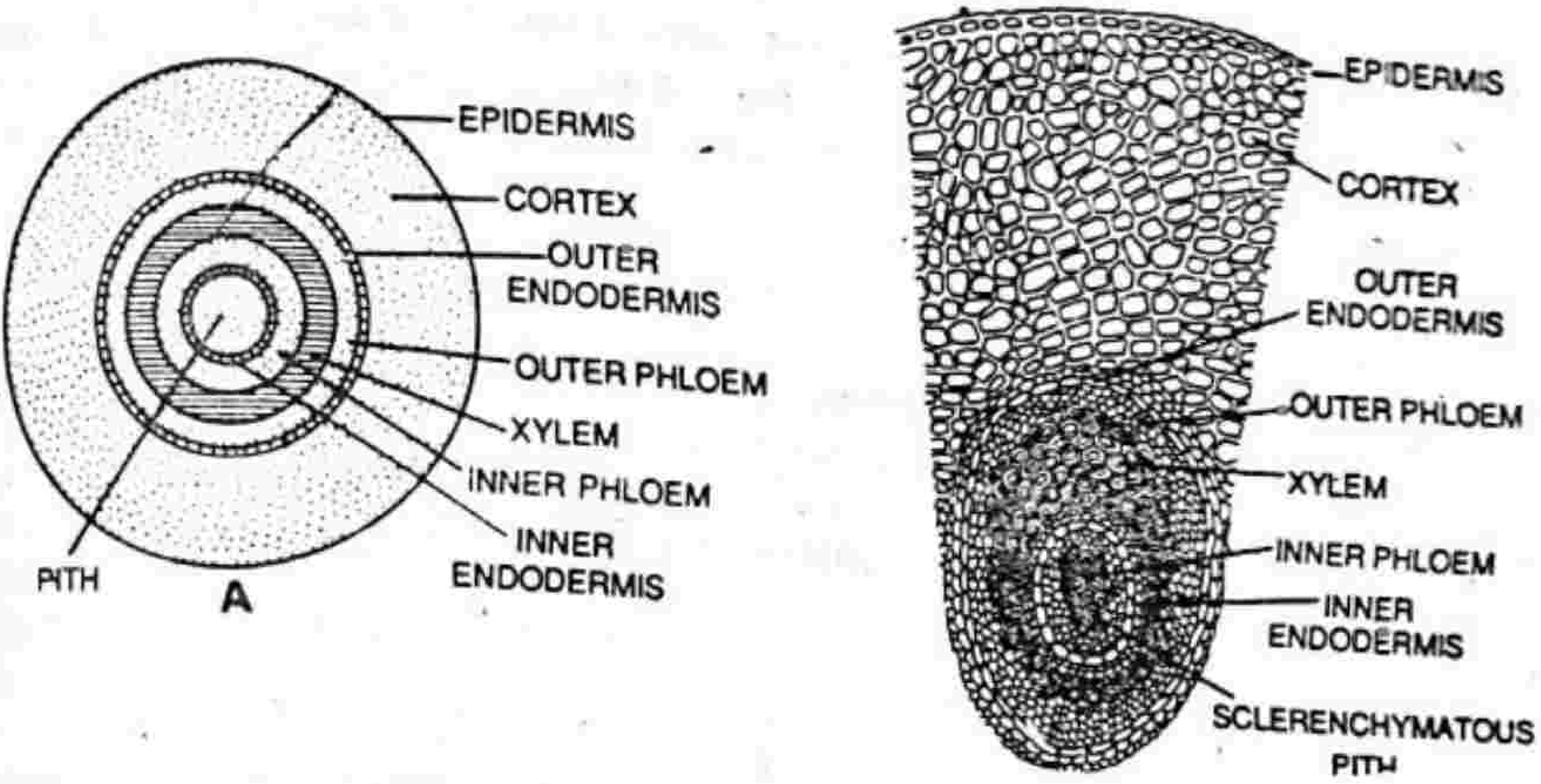

Fig. 7.35: Adiantum — Internal structure of rhizome.

ANATOMY OF LEAF

Petiole

A transverse section of petiole is almost circular in outline. It is protected with a single layered epidermis. Beneath the epidermis one to many layered hypodermis composed of sclerenchyma is present. Hypodermis is followed by parenchymatous ground tissue. The petiole is connected to stem stele by one or more traces, that run throughout the rachis giving rise to branches that enter the pinnae and pinnules.

Leaf Blade

Both the surfaces of leaf blade are covered with epidermis. The lower epidermis contains a number of stomata. The epidermal cells contain chloroplasts and their outer surfaces are covered with a thin cuticle. In between the epidermal layers a relatively undifferentiated mesophyll is present. The mesophyll cells are limited in extent, therefore epidermal cells play major role in photosynthesis. The veins (vascular tissue) are composed of collaterally arranged xylem and phloem. The phloem faces the lower epidermis and xylem upper epidermis. In some species the veins are surrounded by sheath of sclerenchyma cells.

Anatomy of Root

The outermost layer is epidermis composed of small cells. Beneath epidermis there is sclerenchymatous cortex surrounded by a prominent endodermis. The endodermal cells have Casparian bands. The stele is protostele and surrounded by pericycle.

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REPRODUCTION

The life cycle in *Adiantum* is characterized by alternation of generations. Both the spore- and gamete-producing generations are independent.

Asexual Reproduction — (Sporophyte) = spore producing body.

The asexual reproduction is by formation of spores in sporangia which group to form sori. After a series of vegetative leaves have been produced from the stem, development of fertile leaves start alongwith the vegetative leaves. The spore-bearing structures, the sporangia develop on these leaves in groups called the sori. The spores are alike, therefore the plant is homosporous.

The Sori

The sori (Gr. soros=heap) are groups of sporangia that develop at the margins on the underside of fertile leaves called sporophylls. The sori are covered with a flap of tissue called the false indusium (L. indusium=a woman's undergarment) during development. The sporangia are actually borne on this false indusium.

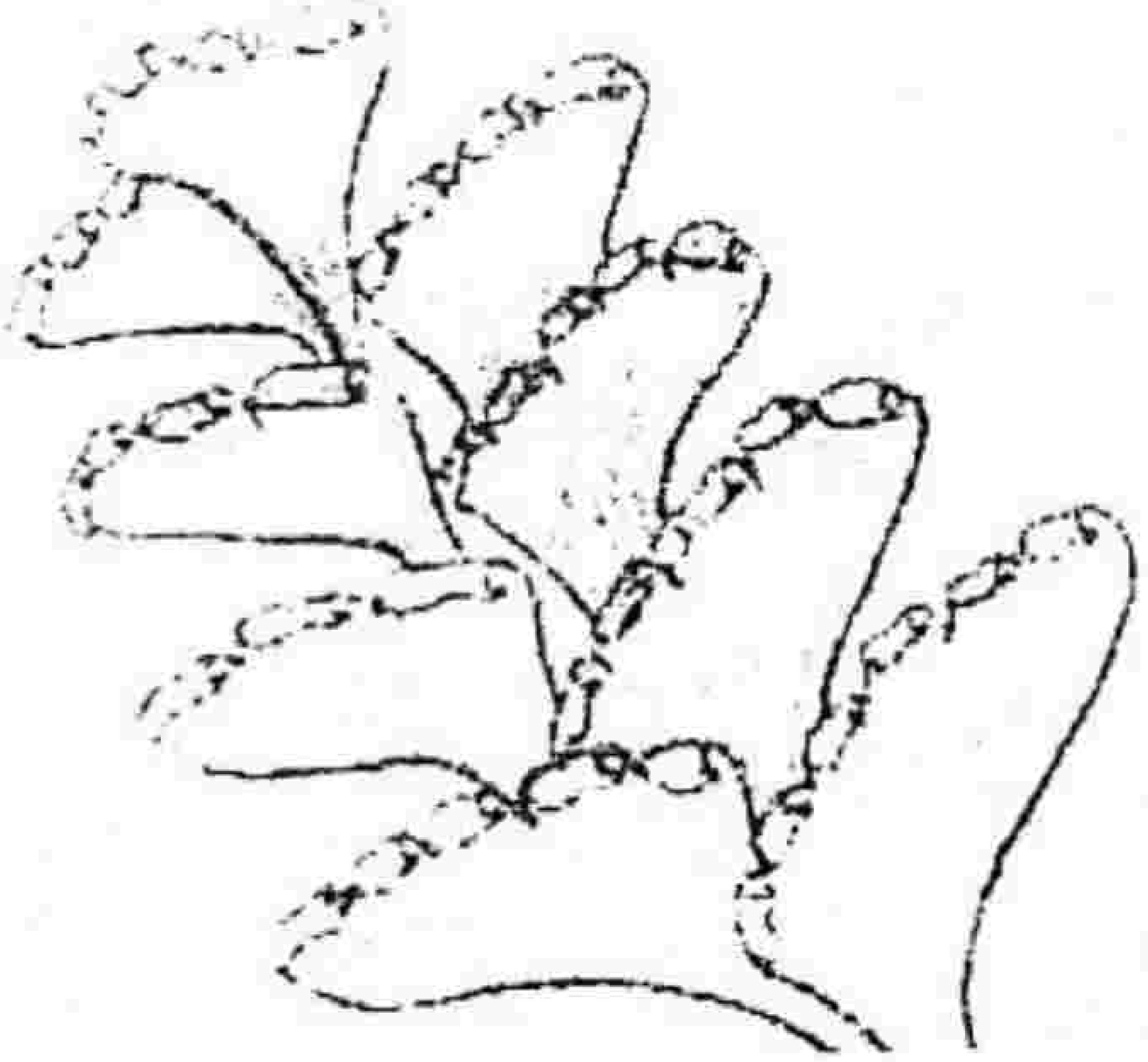


Fig. 7.36: Adiantum — A sorus and structure of sporangium.

Structure and Development of Sporangium

A mature sporangium is flattened, spherical or ellipsoidal. It consists of a stalk and an enlarged upper end usually called a capsule.

Capsule

The capsule contains sporocytes enclosed by a single layered wall.

Annulus

The wall of the sporangium is distinct vertical row of specialized cell which form an incomplete ring about the sporangium which is called as annulus. The radial and inner tangential walls of these cells are thickened.

Stomium

Between the last cell of the annulus and the sporangium stalk, there are usually four thin-walled cells called lip cells or stomium. The stomium help in dispersal of spores.

Development

Each sporangium arises from the lower leaf surface and the region of its origin is called receptacle. A superficial cell of the receptacle acts as sporangial initial. It projects above the surface of the receptacle and divides by an oblique division into a basal cell which does not take part in development, and an outer cell that develops into sporangium. The outer cell divides by three oblique walls to form a tetrahedral apical cell with three cutting faces. It cuts off segments and lower segments give rise to the stalk, while the upper segments contribute to sporangium wall. The apical cell stops cutting segments and divide by a periclinal wall to give rise to jacket initial and central archesporial cell. The jacket initial alongwith three upper segments develop into sporangium wall. The archesporial cell (primary sporogenous cell) cuts off primary tapetal cells which divide to form the tapetum. The archesporial cell undergoes repeated divisions to form spore mother cells. Each spore mother cell undergoes meiosis to form a tetrad of spores.

Dehiscence of Sporangium, Release and Dispersal of Spores

The thin outer tangential walls of the annulus lose water, shorten in length and become concave so that the sporangium wall ruptures at stomium. The sporangium wall moves back or catapult ejecting the spores. Each spore is tetrahedral and spore is differentiated into two layers, the outer ornamented exine and inner intine. The spores are dispersed by air currents and only a few of these germinate into gametophytes because most of these are carried to places unsuitable for germination.

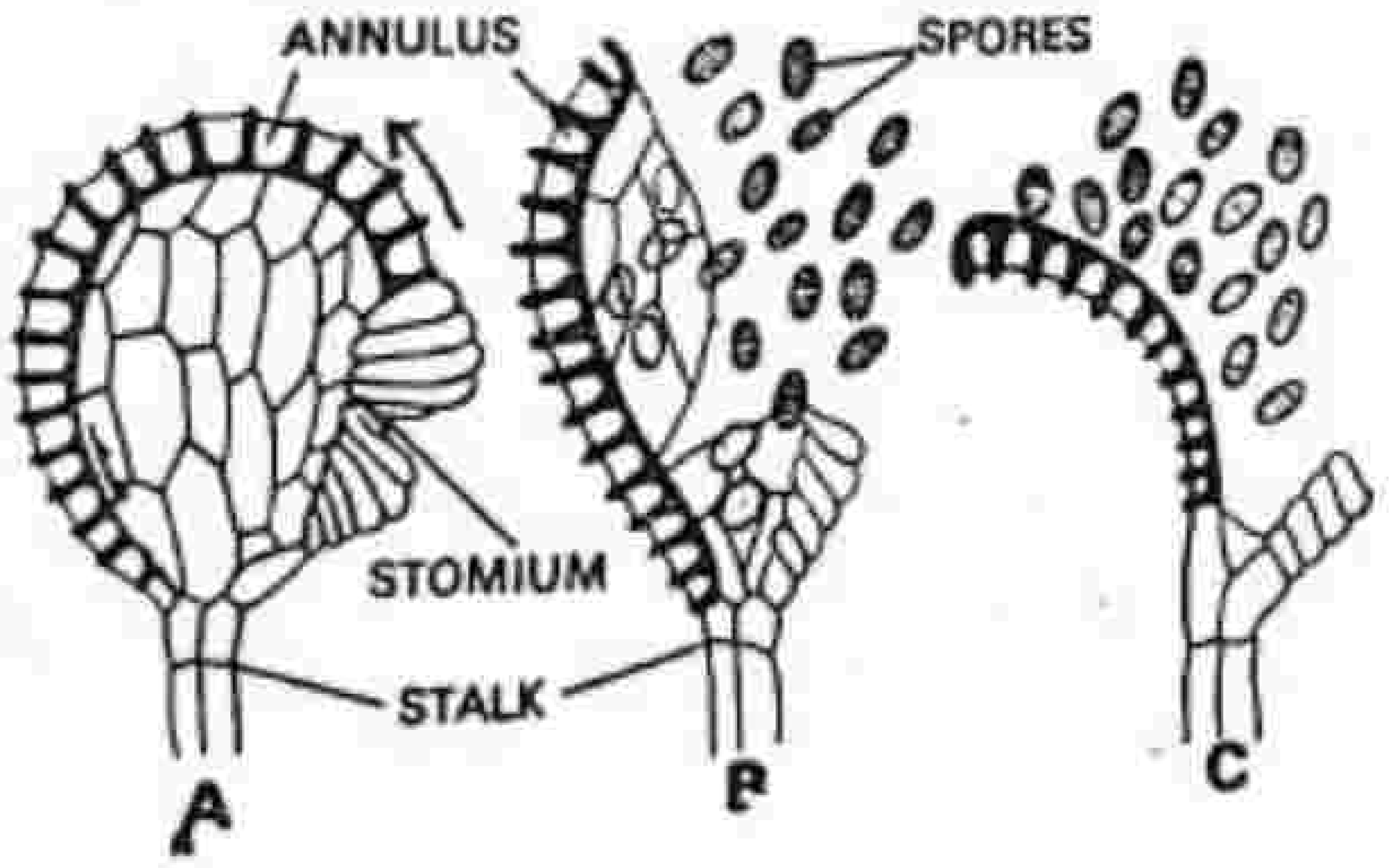


Fig. 7.36a: Adiantum — Dehiscence of sporangium.

Germination of Spore

Upon reaching a suitable place for growth, the spores absorb moisture, increase in size and the exine ruptures at the triradiate ridge. The intine protrudes out to form a small filament, the germ tube. It divides into a smaller basal cell which give rise to first rhizoid and a larger apical cell with two cutting faces. It cuts off segments in two directions. It is soon replaced with a transverse row of cells lying in apical notch. The activity of these cells result in a spatulate prothallus or gametophyte.

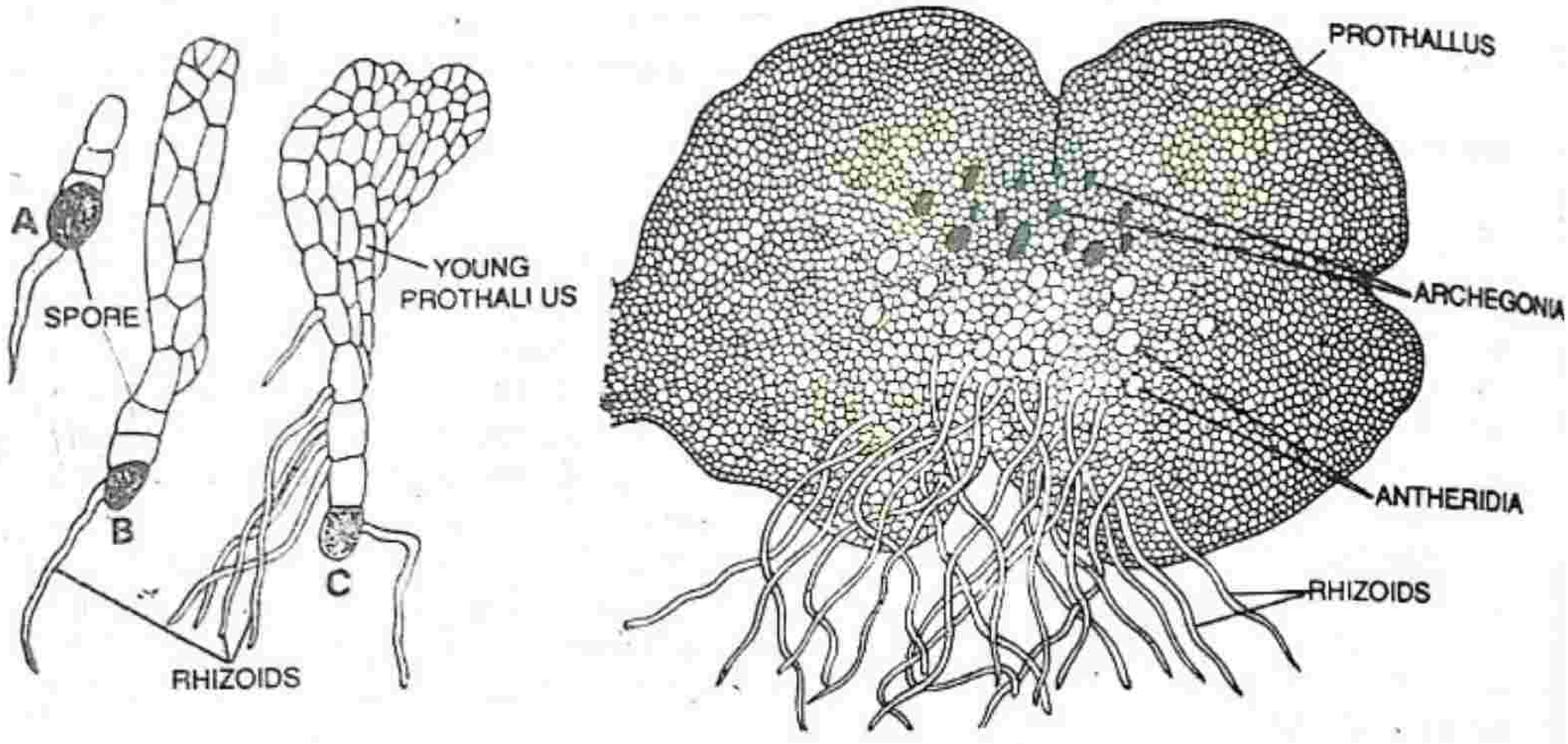


Fig. 7.37: Adiantum — Structure and Development of prothallus.

GAMETOPHYTE

The prothallus of *Adiantum* is heart shaped structure. It is several cells thick in middle but remains single layered at the margin. Several cells on the ventral side produced rhizoids. The rhizoids absorb water and also fix the prothallus to the soil. All the cells of prothallus are green in color and contain a single disc shaped chloroplast. The prothallus of *Adiantum* is completely independent as it manufacture its own food. There is no mycrorhizal fungus in the prothallus.

Sexual Reproduction

The gametophyte is monoecious and usually protandrous.

Sex Organs

The sex organs antheridia and archegonia produced on the same prothallus. The antheridia are projecting and develop first near the posterior part of the gametophyte among the rhizoids. The archegonia develop in the thickened central cushion. The neck of the archegonium projects above the surface of the thallus.

Structure and Development of Antheridium

A mature antheridium is globular and consists of a 3-celled wall enclosing spermatocytes. The wall consists of three cells, two of them ringlike and the uppermost a cap or cover cell.

Each antheridium develops from a single superficial cell of the gametophyte. It protrudes out to form a hemispherical cell which divides by a funnel-shaped wall to form a dome-shaped upper central cell and a lower first ring cell. The central cell divides by a curved wall into an outer jacket cell and a primary androgonial cell. The jacket cell undergoes division to form an upper cap or cover cell and second ring cell. The first and second ring cells and cover cell constitute the antheridium wall. The primary androgonial cell divides repeatedly to form 16-32 sperm mother cells, each of which metamorphoses into a multiflagellate male sperm.

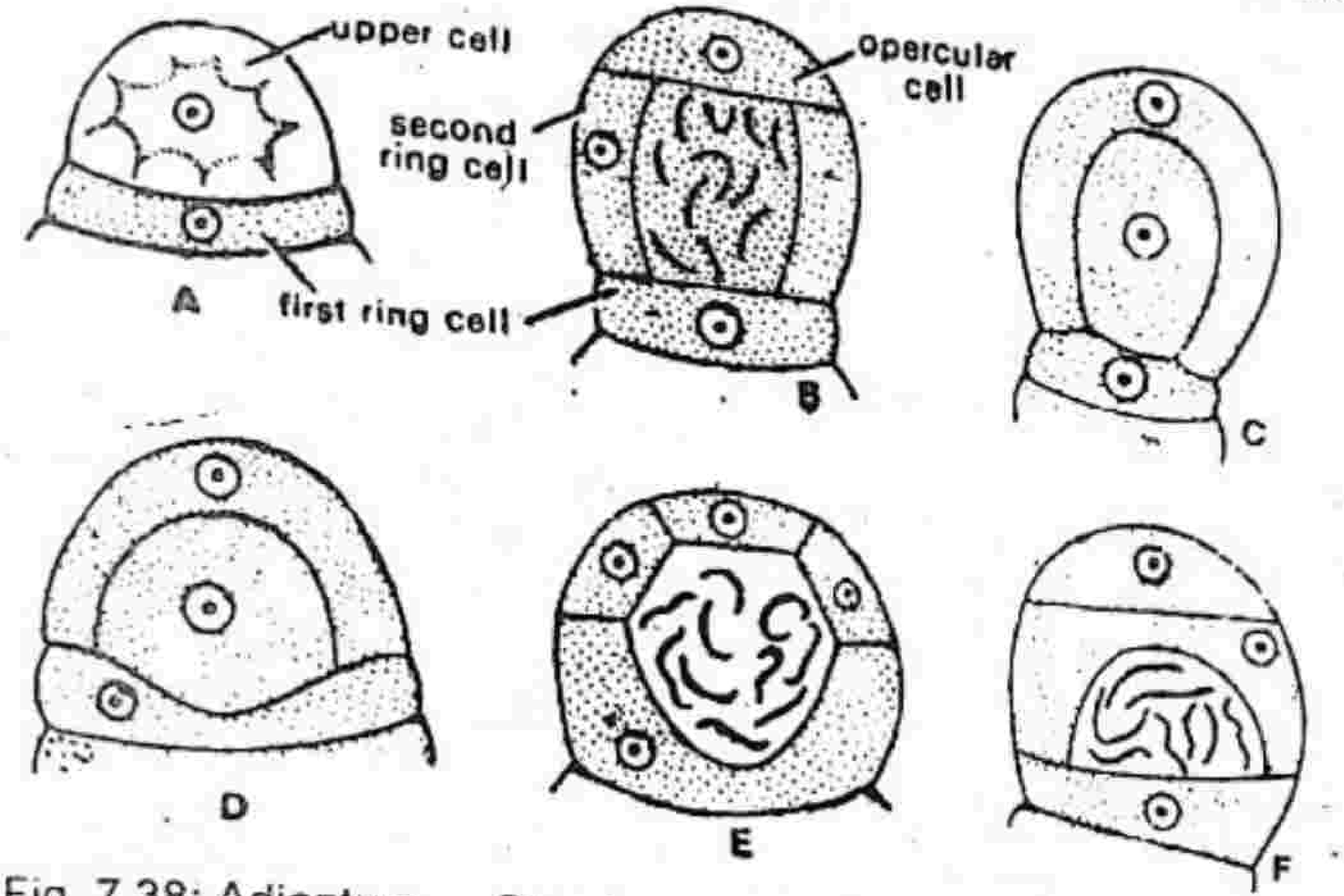


Fig. 7.38: Adiantum — Structure and development of antheridium.

Structure and Development of Archegonium

A mature archegonium is flask-shaped and consists of a basal swollen base, the venter embedded in the gametophyte tissue, and a slightly projecting recurved neck. The neck encloses a binucleate canal cell while the venter contains an egg and a ventral canal cell.

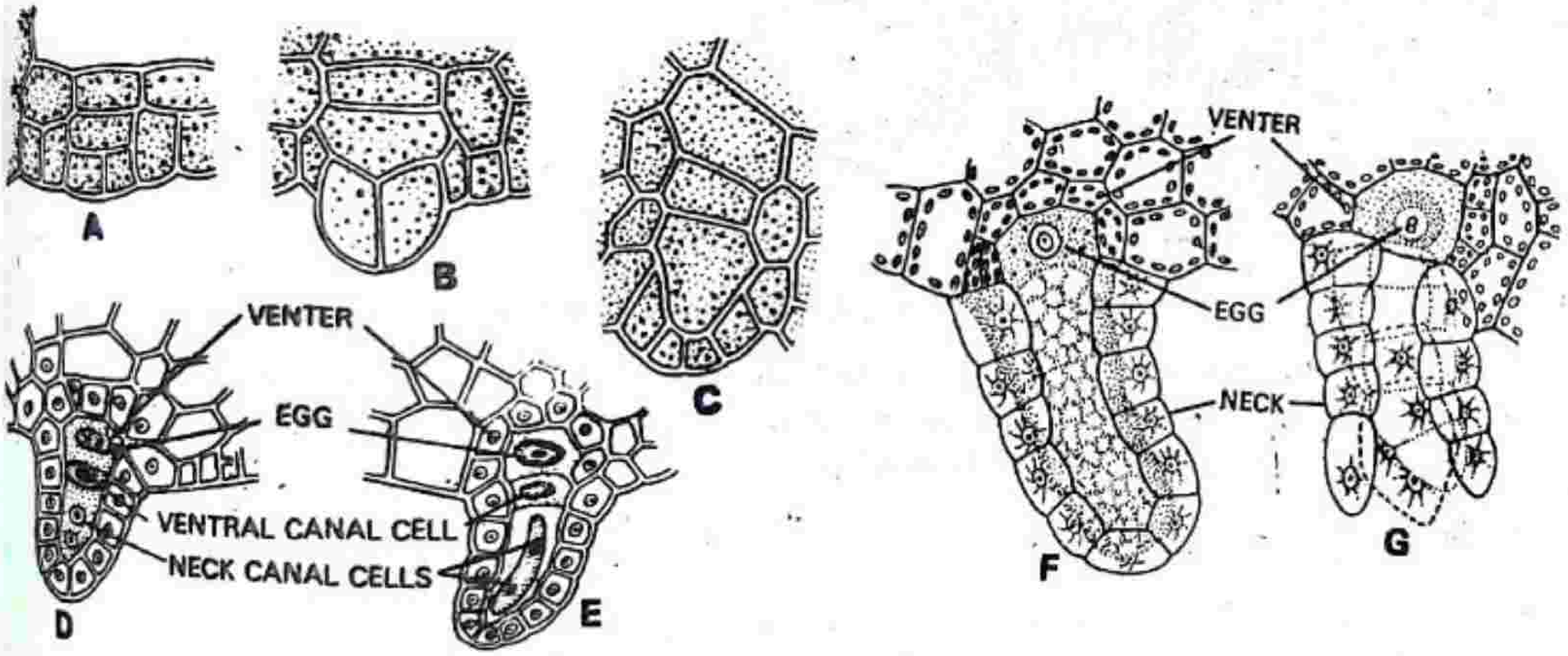


Fig. 7.39: Adiantum — Structure and development of archegonium.

Each archegonium develops from a surface cell of the gametophyte. It divides by a transverse division into an outer cell which divides by two successive anticlinal divisions to give rise to a vertical row of four neck initials; and an inner cell. The inner cell divides periclinally to form a basal cell which does not take part in further development, and a central cell that divides by periclinal divisions to give rise to an axial row of egg cell, a ventral canal cell, and a long narrow binucleate neck canal cell.

Fertilization

The antheridium takes up water and its components swell up. The cover cell ruptures to release sperms. At the same time the neck cells of archegonia disintegrate due to absorption of water. The neck and ventral canal cells become mucilaginous. This mucilage contains malic acid which attracts the male sperms. Many male sperms swim to the egg but only one succeeds in fertilizing it to form the zygote. The cells of archegonial venter start dividing and form a cap-like structure known as calyptra around the zygote.

The zygote starts developing into embryo immediately after fertilization. The zygote divides by a vertical wall parallel to the long axis of the neck forming two cells. A wall at right angle to the first one is laid and results in formation of a quadrant. The upper two cells are epibasal and lower two are hypobasal cells. Another vertical division at right angles to second one produce an 8-celled octant. The cells of epibasal half give rise to stem and cotyledons and the cells of the hypobasal half differentiate into root and foot. The foot absorbs nutrition from the gametophyte tissue and keep pace with developing embryo till formation of root and first leaf.

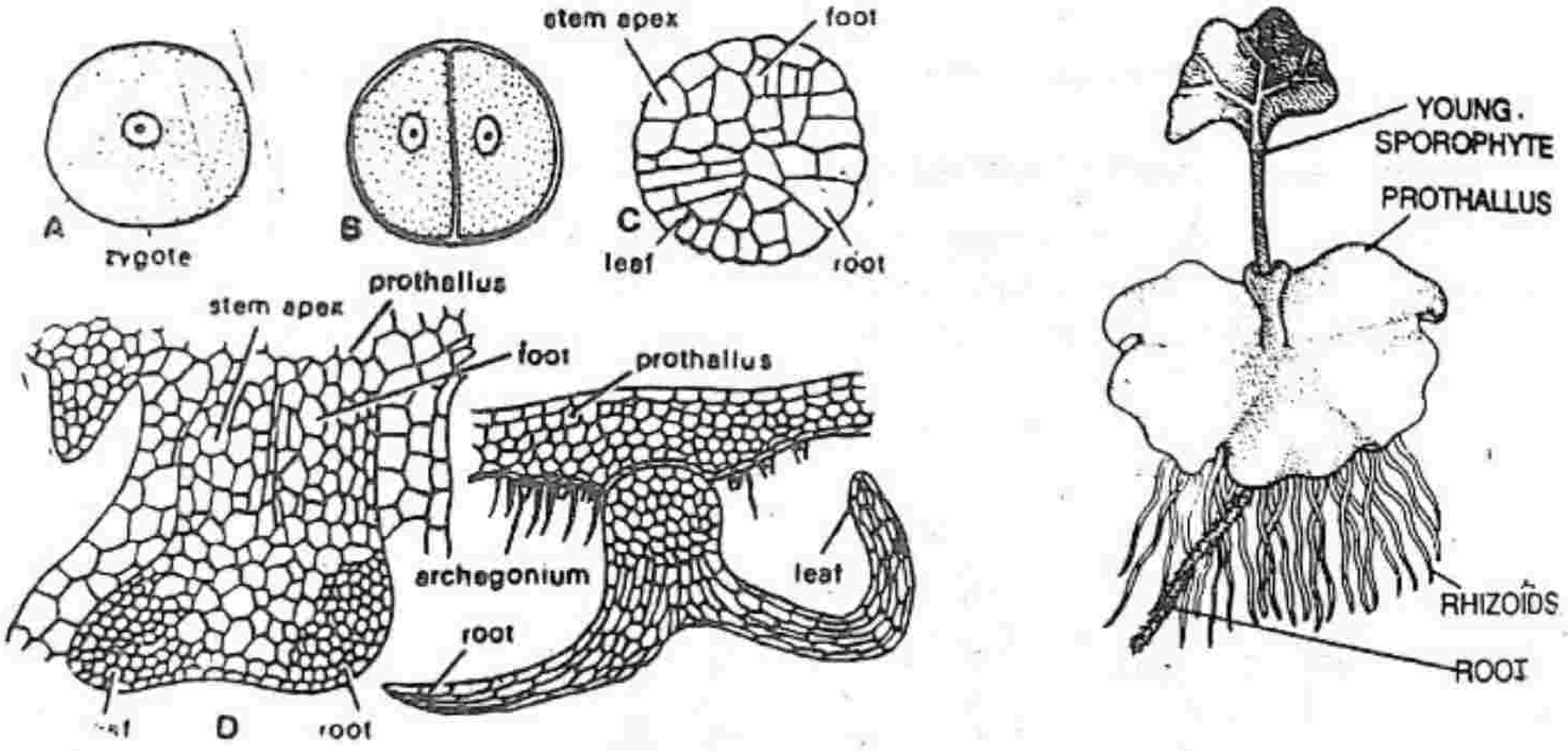


Fig. 7.40: Adiantum — Development of sporophyte.

The root anchors the young sporophyte and first leaf emerges through the apical notch of the prothallus. It turns green and start photosynthesis. The stem grows underground and bears adventitious roots.

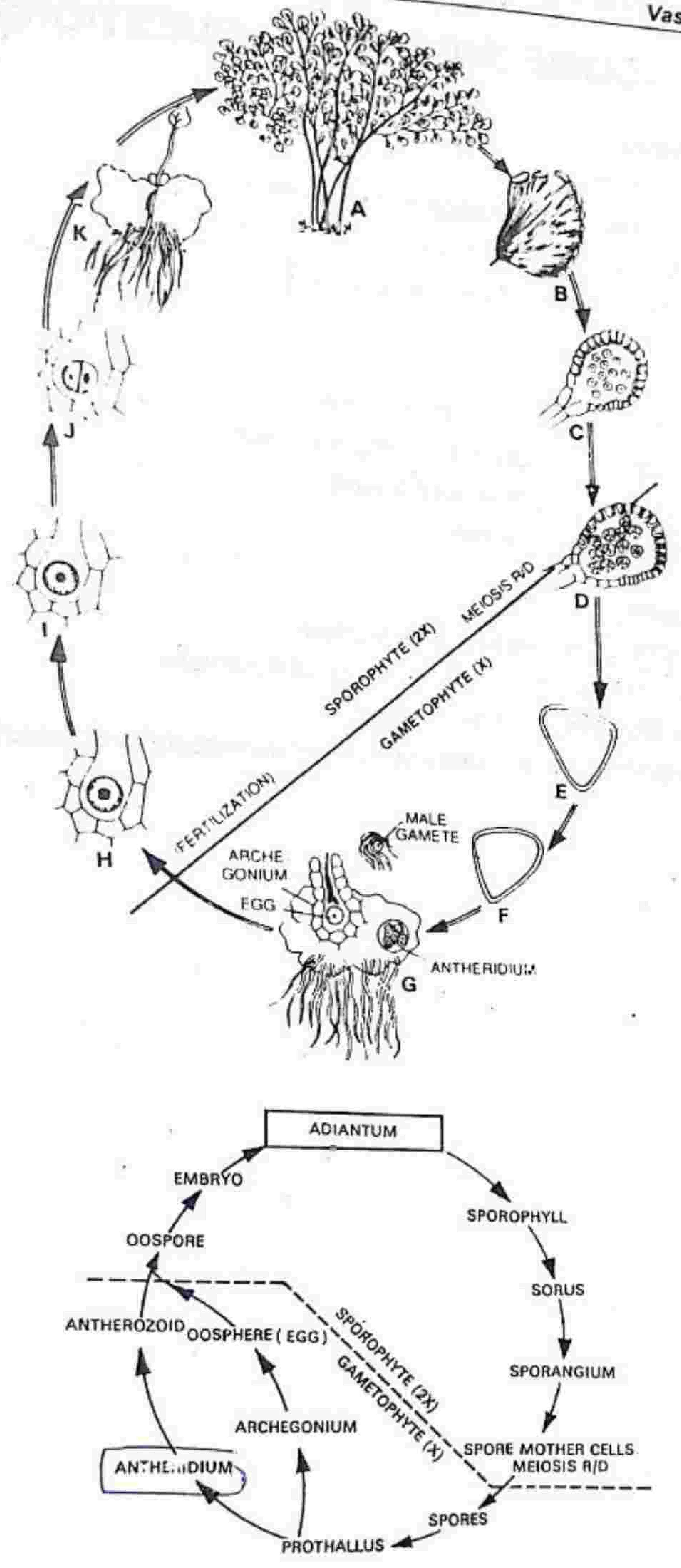


Fig. 7.41: Adiantum — Life Cycle.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are ferns.
2. What are taxonomic position of Adiantum.
3. Enlist the habitat of Adiantum
4. Which type of stele is found in Adiantum.
5. What is frond.
6. What is sorus.
7. What is stomium. Give its importance.
8. is gametophyte of Adiantum is photosynthetic.
9. Draw diagram of prothallus of Adiantum.
10. Draw life cycle of Adiantum.

B. Long Questions

1. Write a note on sporophyte of Adiantum.
2. Describe internal structure of rhizome of Adiantum.
3. Describe life history of Adiantum.
4. Write note structure and development of gametophyte of Adiantum.

LEPTOSPORANGIATE FERNS

(i) Leptosporangiate ferns differ from other ferns in having a sporangium with a jacket layer one cell in thickness, a definite number of sores within a sporangium, a development of sporangium from a single initial cell, and a differentiation of the tapetum from a single internal cell of a developing sporangium.

(ii) Sporangia are borne marginally and when grouped in sori these do not unite to form a synergism.

(iii) Antheridia differ from other ferns in being small, more or less emergent, and contain a few male sperms.

(iv) The foot, primary root, cotyledon, and stem of young saprophyte, each develop from a single cell of four-celled embryo.

POLYPODIUM

Taxonomic Position

Division:	Filicophyta
Class:	Leptosporangiopsida
Order:	Filicales
Family:	*Polypodiaceae*
Genus:	*Polypodium*

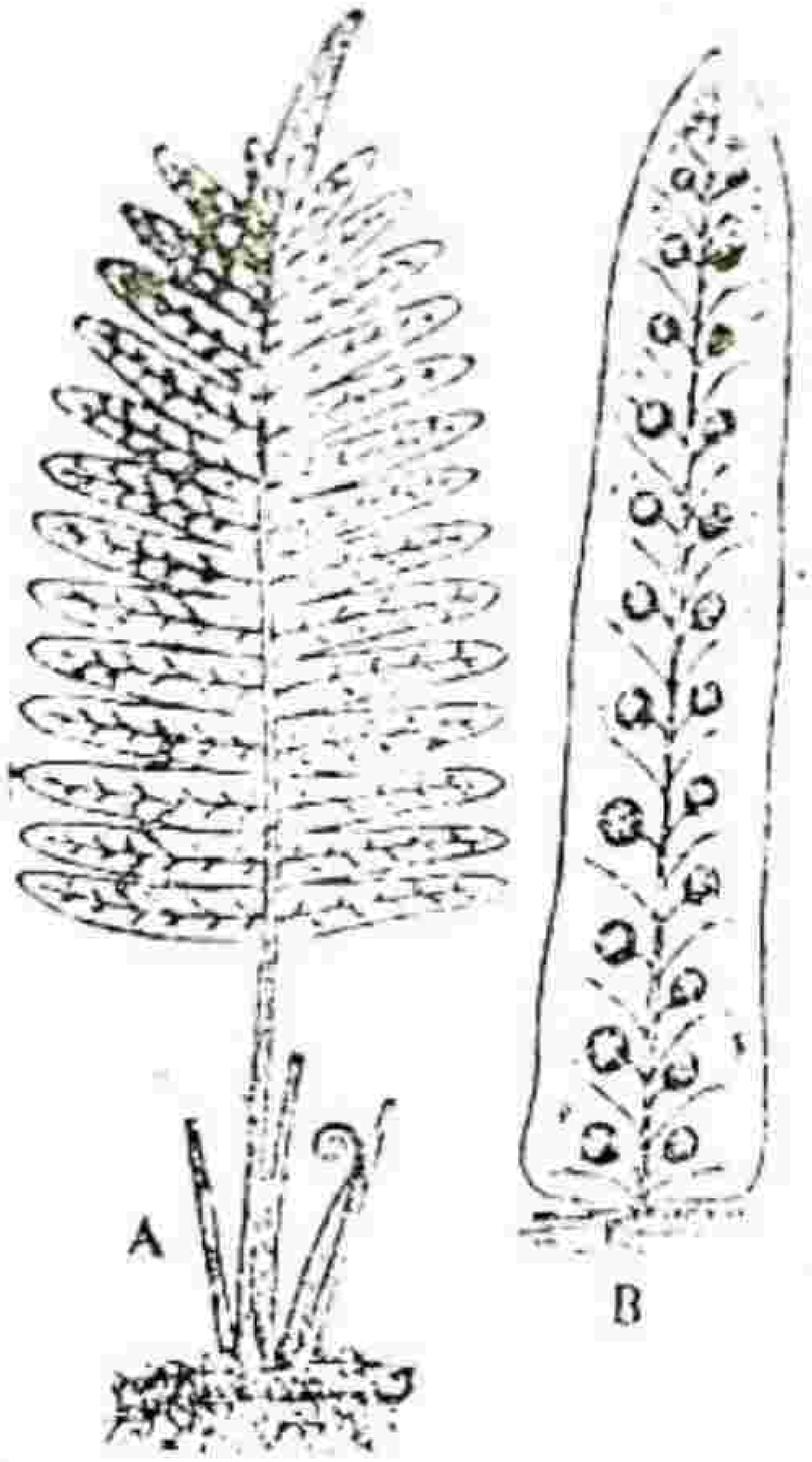


Fig. 7.42: A Polypodium

Polypodium is a large genus of true ferns, widely distributed throughout the world. The genus includes about 50 species of leaf-losing (deciduous) and hardy evergreen ferns that are found in many parts of the world including tropical, semitropical and temperate areas. The name is derived from Gr. *Poly*=many, and podium=a little foot, on account of the foot-like appearance of the rhizome and its branches. These differ greatly in size and general appearance and in the character of the frond; the sporangia are borne on the back of the leaf, are globes and naked, i.e., not covered with indusium. These are*Polypodium vulgare, Polypodium dryopteris, Polypodium phegoptenis etc.*

Vegetative Morphology — Saprophyte

The plant body consists of creeping, slender branched rhizome that grows to 2 mm in diameter. It is covered with lanceolate scales, with light brown base and margins, and having a dark central stripe. The leaves are bright green, thin and tough and may vary from only a few inches to 6 feet long. They may be pinnate (feathery-divided once), bipinnate (divided twice), or simple (undivided). The older portions of rhizome are covered with bases of old leaf. The younger leaves exhibit circinate coiling. Both leaf lamina and stem are covered with muticellular hair. The roots are adventitious, branched and produced in large numbers from lower surface of rhizome. The growth of plant body is by a three-sided apical cell that cuts off segments from its three sides that develop into new tissues.

INTERNAL MORPHOLOGY — ANATOMY

Rhizome

The boundary layer is epidermis that is characterized by presence of one-cell thick scale-like modified hairs called ramenta. Beneath the epidermis there is a many-layered cortex. The outer few layers of cortex are sclerenchymatous while the rest consists of parenchyma. The stele comprises of vascular bundles. The stele is meristele. i.e., the vascular bundles are separate and are embedded in the inner cortex in the form of an irregular ring. Each meristele comprises of central mass of xylem surrounded by phloem. The xylem consists of tracheids and xylem parenchyma. Phloem comprises of a single ring of large sieve tubes and phloem parenchyma. Each meristele is completely surrounded by endodermis. The endodermal cells possess distinct Casparian strips.

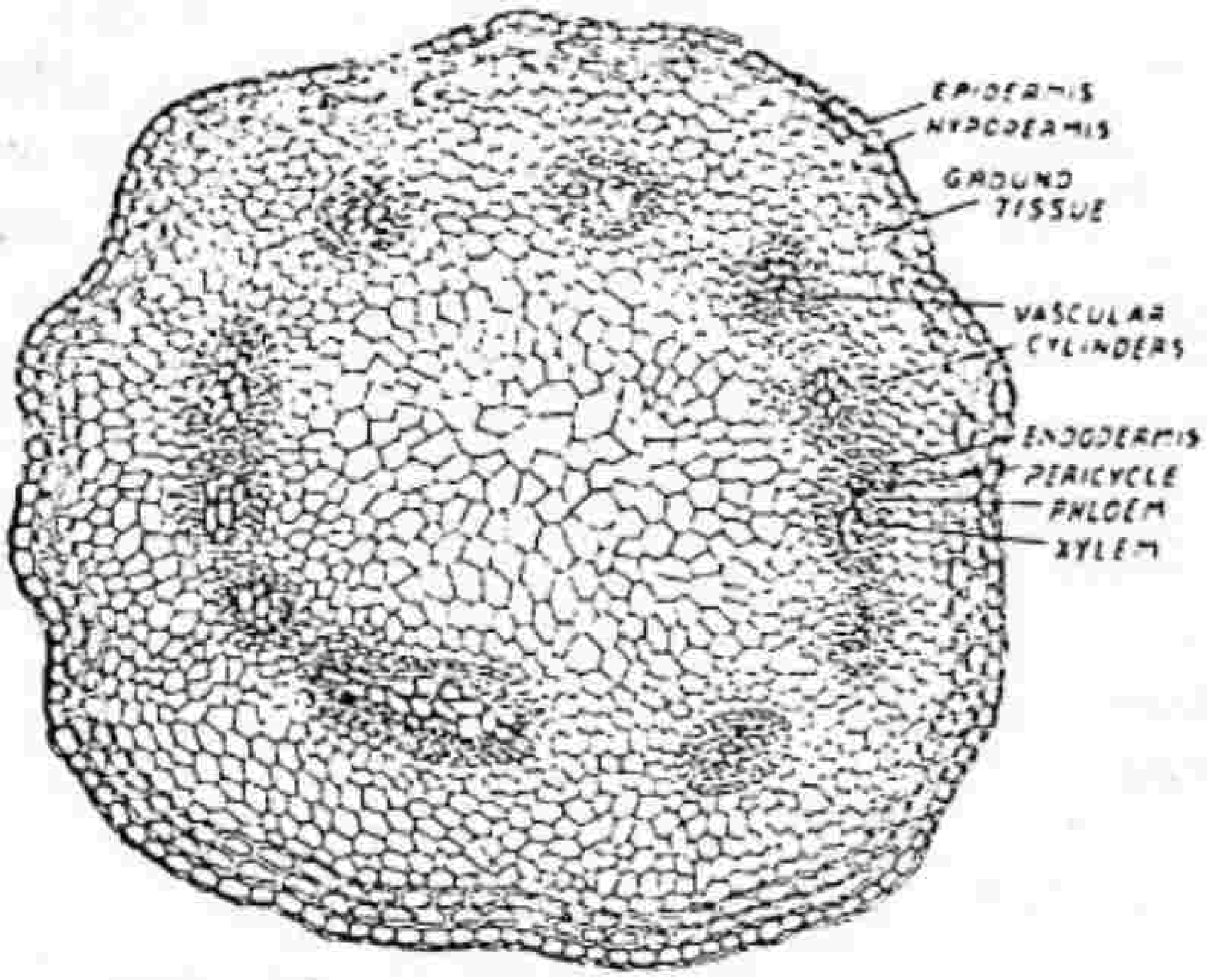


Fig. 7.43: Internal Structure of Rhizome.

Leaves

The leaf lamina is bounded by upper and lower epidermis. The stomata are restricted to lower epidermis. The leaf epidermis is covered with club-shaped multicellular hair. The mesophyll consists of irregular parenchyma cells with well-developed intercellular spaces. Both epidermal and mesophyll cells contain chloroplasts. The vascular bundles are concentric. The vascular bundles in petiolar regions are arranged in horseshoe like manner.

Root

The centre of root is occupied by stele. It comprises of a central core of diarch xylem with tow protxylem groups situated at its ends surrounded by phloem. A two-layered pericycle surrounds the phloem. Next to it is endodermis whose cells are characterized composed of chick-walled sclerenchyma and outer cortex consisting of thin-walled parenchyma. Outside the cortex a single layered epidermis is present.

ASEXUAL REPRODUCTION

Sori

Polypodium is a homosporous fern. The spores are produced in sporangia that group into sori. The sori develop in two rows along both sides of mid rib on ventral surface of a vegetative leaf. Each sours is spherical and is characterized by absence of indusium. The sporangia are borne on receptacle. The hair or peltate scales may also develop among sporangia that protect them.

Structure and Development of Sporangium

Sporangia are yellow to brown at maturity and produce spores from summer to fall. A mature sporangium is slightly flattened ellipsoid and consists of a stalk and an enlarged distal portion, the capsule. A vertical row of specially differentiated cells forms an incomplete ring called annulus about the sporangium. The radial and inner walls of these cells are thick. Between the last cell of annulus and sporangial stalk there are a number of thin-walled cells, the lips cells or stomium.

Each sporangium arises from a superficial cell of the receptacle that projects above the surface and undergoes a transverse division. The lower celldoes not take part in further development. The upper cell divides by two oblique walls to produce a tetrahedral apical cell. It cuts off segments along its three sides. The lower segments develop into stalk. The apical cell divides by a curved transverse wall into an inner sporogenous cell and an outer jacket initial. The jacket initial alongwith three segments cut off by apical cell now surround a central cell. The jacket initials divide anticlinally to give rise to sporangial wall. The archesporial cell cuts off four tapetal initials that divide periclinally first and then anticalinally to produce tapetum and inner wall layer. The sporogenous cell divides to form spore mother cells which undergo reduction to produce 48-64 spores.

The spore protoplast is surrounded by two-layered wall, the exine and intine. The outer wall is thick while the inner wall in thin.

Dehiscence of Sporangium

Dehiscence of sporangium depends on loss of water. The annulus and lip cells take part in this process. The loss of water shorten its length so that the sporangial wall is ruptured transversely in the region of the lip cells. The outer wall cells of sporangium cell also rupture. As the annulus continues to shorten, its outer tangential cell walls become increasingly concave and finally it catapults ejecting the spores .

PROTHALLUS (GAMETOPHYTE)

The spore, upon germination produces gametophyte called prothallus. The spore produces a filament of three to six cells which remain undivided except for the terminal cell that by two oblique vertical divisions, gives rise to an apical cell that cuts off segments alternately right and left. Later the apical cell is replaced by a transverse row or apical initial. If conditions for growth are favourable, the gametophyte becomes heart-shaped because of more rapid growth of portions lateral to the apical initials. It possesses an apical notch.

At first the prothallus is once cell in thickness, later it becomes more than one cell in thickness in the region posterior to the apical notch. The first rhizoid is developed at the two-called stage and with further growth additional ones are produced near the posterior end and on the ventral side. The prothallus is monoecious, i.e., bears both male and female sex organs, the antheridia and archegonia.

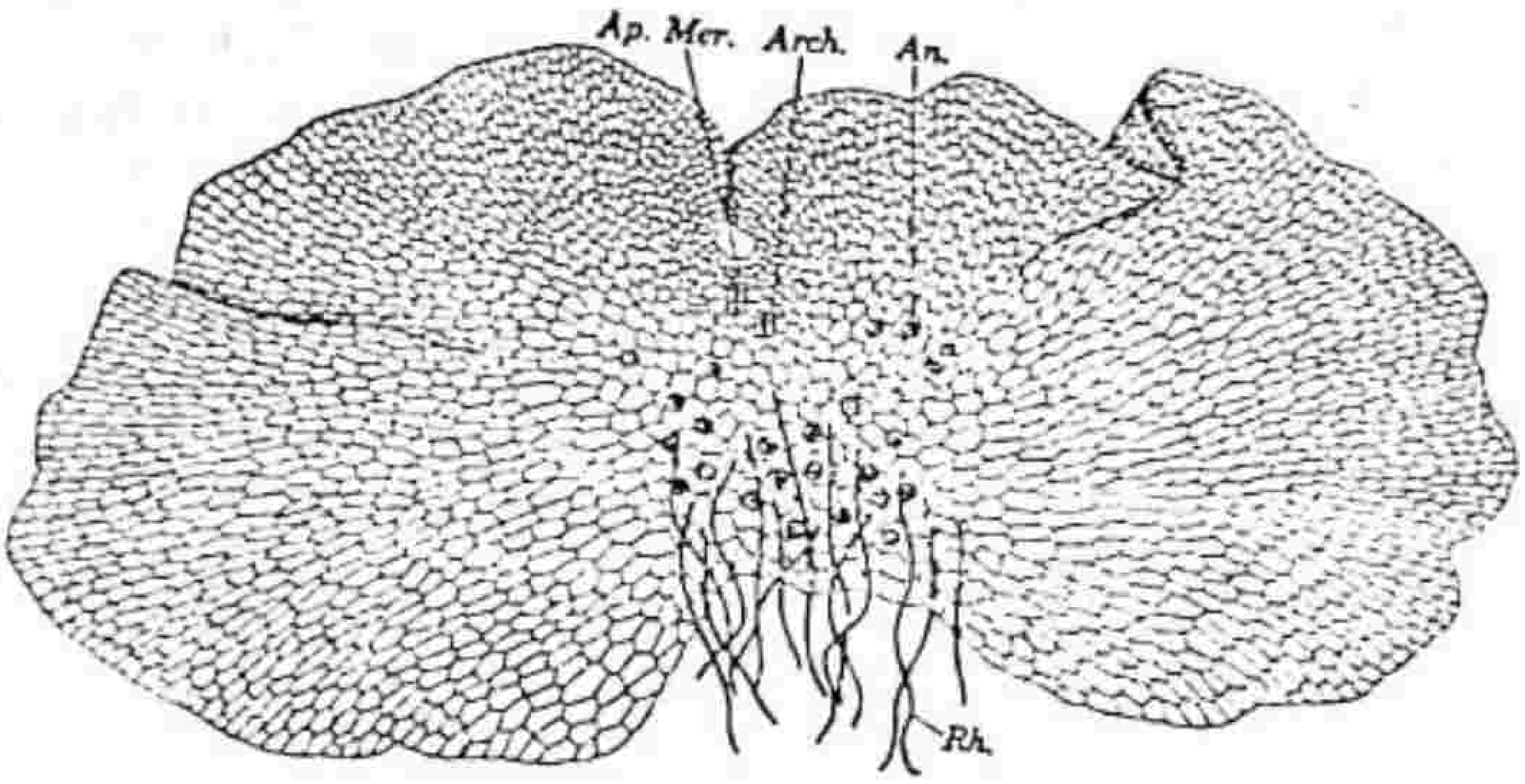


Fig. 7.44: A Prothallus.

Structure and Development of Antheridium

Antheridia are produced along the margins in the central region of posterior portion of gametophyte. Formation of antheridia begins before that of archegonia.

A vegetative cell of prothallus acts as antheridial initial that develops into papilla which becomes separated by a cross wall. It divides by a transverse wall that is pushed toward the base of lower daughter cell called first ring cell. The upper daughter cell divides by a transverse wall into a dome cell and a primary androgonial cell. Transverse division of the dome cell forms the second ring cell and cover cell. The two ring cells and cover cell constitute the jacket portion of the antheridium. The primary androgonial cell divides and redivides to form androgonial cells in which those of last cell generation is androcytes. Each androcyte metamorphoses into spirally coiled multiflagellate male sperms.

Structure and Development of Archegonium

A superficial cell of prothallus acts as archegonial initial. It divides by transverse division to a basal cell, a central, and a primary cover cell. The primary cover cell divides vertically to form four neck initials, and by transverse division these develop into a neck five to seven cells in height. The neck of the archegonium is strongly curved towards posterior end of gametophyte. The central cell gives rise to a primary canal cell, a venter canal cell and an egg. The primary canal cell and venter canal cell disintegrate into a gelatinous mass that comes out at the time of fertilization.

Fertilization

Antheridium wall absorbs water causes swelling of the two ring cells and resulting pressure causes shedding of cover cell. The male sperms swim out from antheridium and move towards the archegonium in response to certain chemotactic stimuli from it. Many male sperms reach base of the archegonium but only one of them enters the egg to form zygote.

Development of Embryo

Zygote divides by a vertical division to produce anterior cell (towards the apex of gametophyte) and a posterior cell. These two cells divide vertically at right angle to first division to produce four cells, each of which divide by transverse walls. This 8-celled embryo gives rise to cotyledon, primary root, stem and foot. Each cell of 8-celled embryo divides simultaneously to produce 16 and then 32-celled stage. At this stage apical cells of cotyledon and primary root are cutoff. The stimulus of fertilization leads to changes in archegonium wall that develops calyptra. Rapid growth of cotyledon ruptures they calyptra and it emerges near the apical notch. Primary root grows downward into the soil. The apical cell of stem becomes functional when cotyledon develops fully. The foot is haustorial organ that absorbs food from the gametophyte during early stages of development.

MARSELIA

Taxonomic Position

Division: Pterophyta
Class: Leptosporangiopsida
Order: Marsileaceae
Family: *Psilotaceae*
Genus: *Marsilea*

Genus Marselia (after Count F. L. Marsigli, an Italian naturalist) is heterosporous and comprises of about 70 species found all over the world

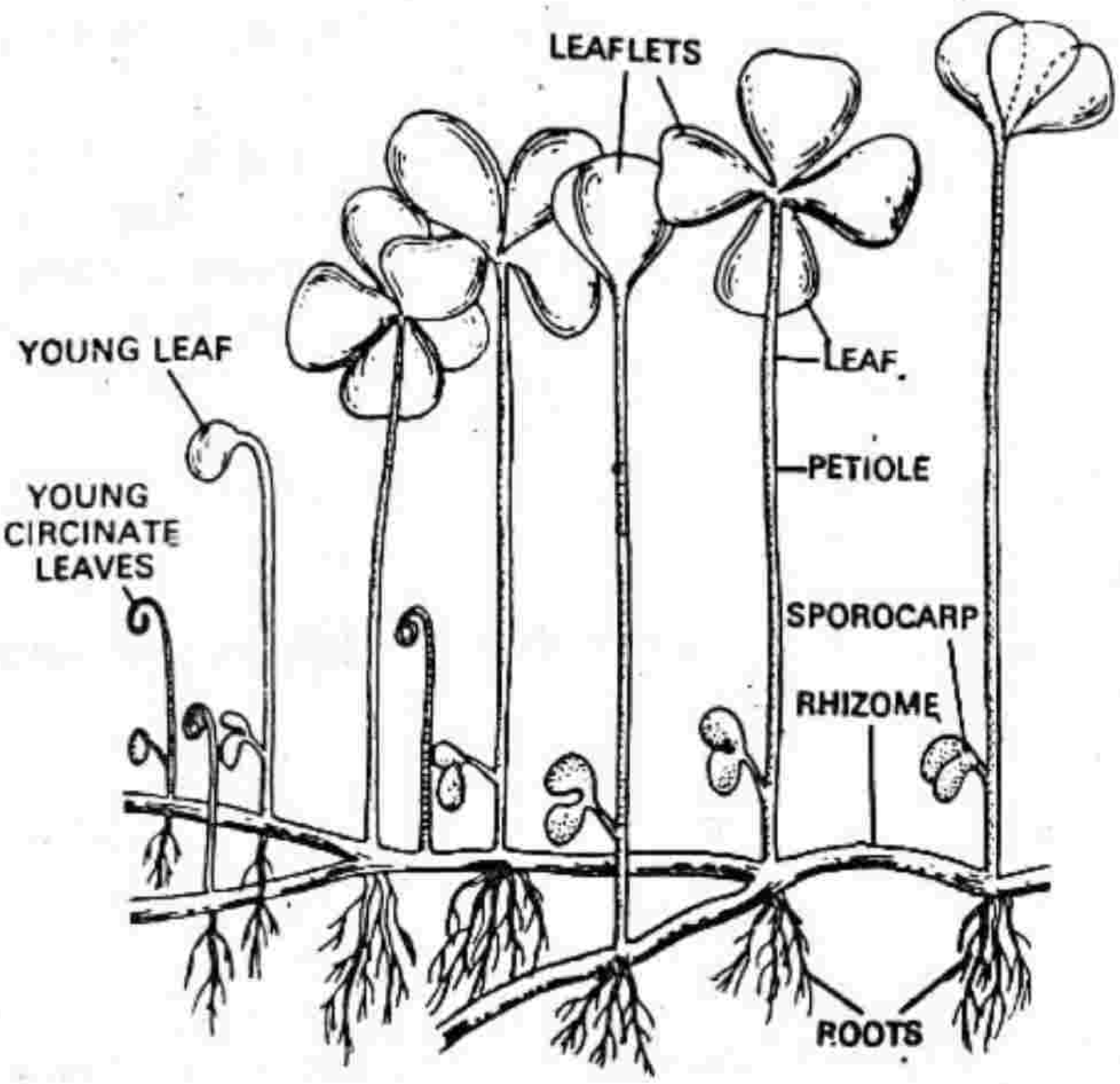


Fig. 7.45: Plant Body.

Occurrence

Marselia inhibit a warm-climate genus, therefore most abundant in tropical area. About nine species have been reported in Indo-Pakistan distributed throughout the sub-continent. The common species are *Marselia quadrifoliata, M. brachypus, M. minuta and M. aegyptica*. Most species grow in shallow ponds and ditches. These are able to survive when the water level falls, as long as the soil is moist. Therefore, they are commonly termed as water ferns. A few species are xerophytic and grow on dry land.

Vegetative Morphology

The vegetative plant body is sporophyte and is differentiated into roots, stem and leaves.

Rhizome

The stem is in the form of creeping rhizome. It has unlimited growth. The rhizome is dichotomously branched and is differentiated into nodes and internodes. The branching is lateral and these arise either in the axil of a leaf, or lateral to or below a leaf. The branches run in all directions and a single plant covers an extensive area.

Roots

Adventitious roots arise from each node on the ventral side of the rhizome. They absorb water and nutrients from the surrounding water.

Leaves

The leaves exhibit typical circinate vernation during development.A single leaf arises from each node. The leaves are compound and each leaf has a long petiole and 4 leaflets. The leaflets are arranged in cruciate manner. The leaf lets are triangular in out line with the broader ends towards the apex.

The petioles in submerged plants are long weak and flexible. They adjust their length with change with the depth of water. The stomata are located in dorsal side of the leaflets. The leaflet veins are dichotomously branched but these become united laterally and near margins to form a loose network. The number of leaflets vary in few species. These may be 5, 6 or 8, however in most species these are four.

INTERNAL ANATOMY

Internal structure of Rhizome

The rhizome under transverse section shows the following demarcations.

Epidermis

The outer surface of the stem is covered by a single layer of epidermis.

Cortex

The cortex very wide and is formed of parenchymatous cells. The cells are thin walled and having no inter cellular spaces in them. There is a ring of large air spaces all around the cortex. It acts as air storage region.

Sclerenchymatous cortex

Below the air spaces there are 2-3 layers of sclarenchymatous tissues.

Endodermis

There is well developed endodermis between the stele and the cortex. It consists of single layer of cells. It is present on the outer as well as inner side of the xylem.

Stele

Next to the endodermis is the steler region. It is amphiphloic solenstele.

Pericycle

It is present just below the endodermis. It consists of a single layer of cells. It is present on the outer as well as inner side of the xylem

Xylem

The xylem is exarch in position. Meta-xylem is toward the inert side while the proto-xylem is toward the arm.

Phloem

It is present on the outer as well as inner side of the xylem.

Pith

There is a pith in the center of the stele. The pith is usually formed of parenchymatous cells.

A single leaf trace arise from the stele in nodal region. It is similar in structure to the single vascular bundle in the petiole.

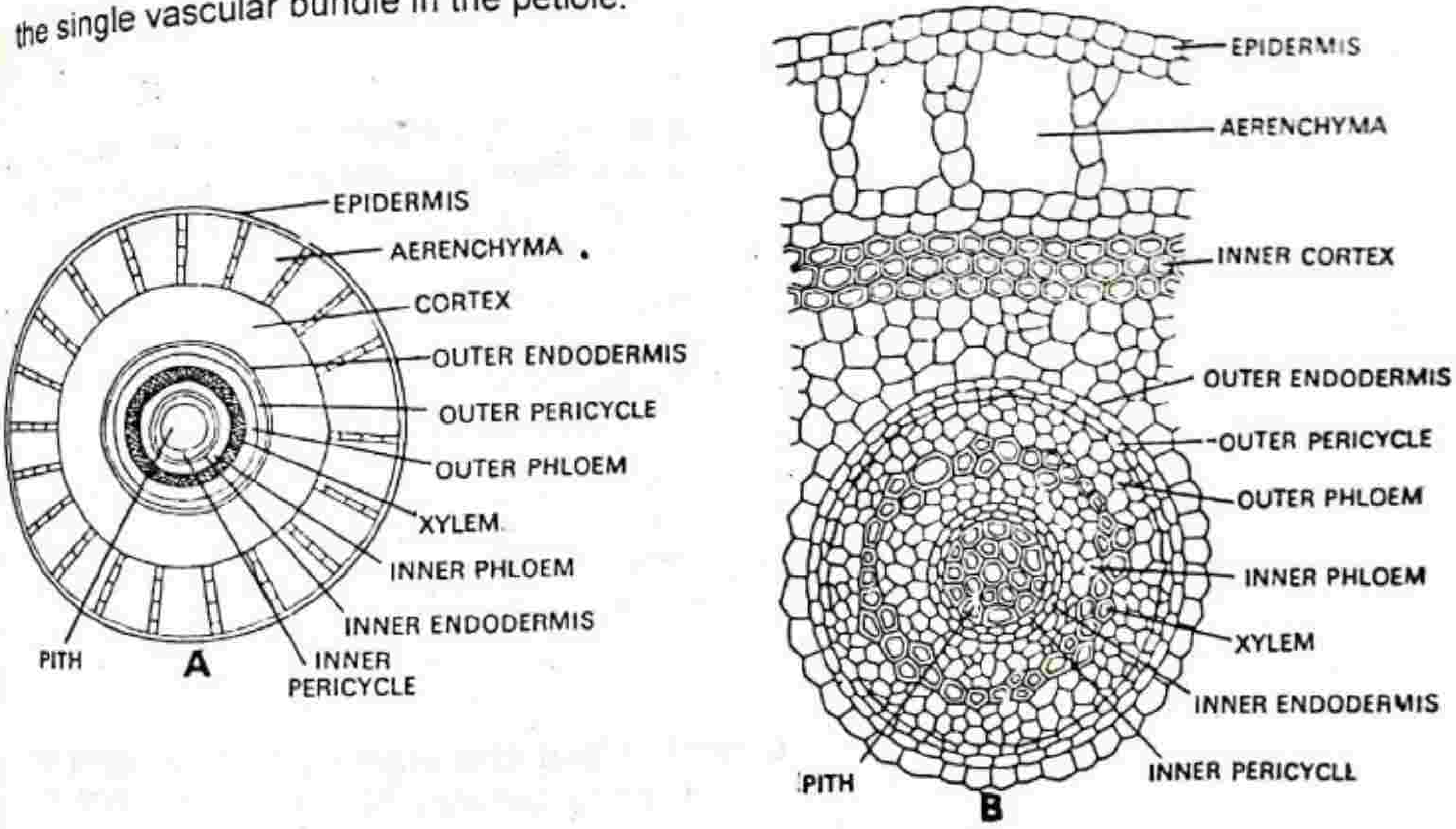


Fig. 7.46: Marselia — Internal structure of stem.

Anatomy of Leaf

Both the leaf surfaces are bounded by epidermis, the upper and lower epidermis. Each layer is formed of thin-walled cells and contains sunken stomata. The epidermal layers are covered with cuticle. In between the epidermal layers mesophyll tissue is present. It is differentiated into palisade and spongy parenchyma. The palisade is present beneath the upper epidermis and it consists of columnar cells that contain chloroplasts. The spongy parenchyma is present above the lower epidermis and it is composed of isodiametric cells. Submerged leaves lack cuticle and mesophyll in them is not differentiated into palisade and spongy parenchyma.

Each leaf is traversed by a single vein (vascular tissue) which comprises of a central core of xylem surrounded by phloem. The vascular tissue is bounded by a single-layered endodermis.

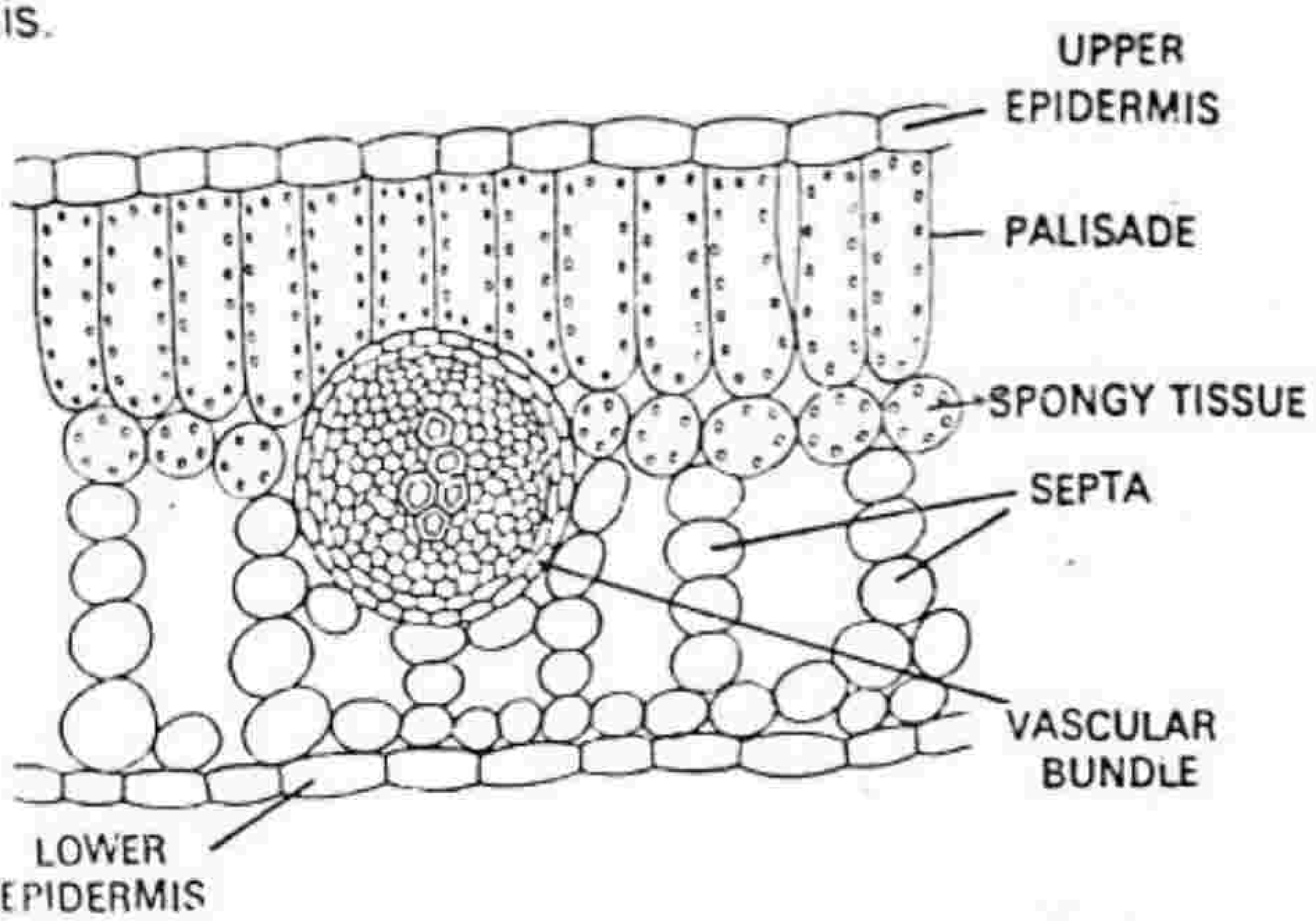


Fig. 7.47: Marselia — Internal structure of leaf.

Anatomy of Root

The boundary layer in root is the epidermis. It consists of parenchymatous biconvex cells. The outer surfaces of these cells are thickened. Beneath the epidermis a broad cortex is present that can be differentiated into outer cortex and inner cortex. The outer cortex is composed of compact isodiametric cells. It contains air chambers arranged in a ring. Each air chamber is separated by thin-walled partitions. The inner cortex consists of thick-walled sclerenchyma cells. The cells contain starch. Next to inner cortex, there is a conspicuous endodermis. It is single layered and formed of thick walled cells.

The stele in root is monarch or diarch protostele. It consists of plate-like xylem that occupies the center of stele. The xylem is exarch. On either side of xylem plate phloem bundles are present. Vessels are reported in the xylem of some species. The vascular tissue is surrounded by a single-layered pericycle. The pith is absent.

Reproduction

The plant is a heterosporous sporophyte and characterized by alternation of generations. Both the sporophyte and gametophyte generations are independent. In addition the plants reproduce vegetatively as well.

Vegetative Reproduction

Marselia minuta and *M. hirsuta* reproduce vegetatively by formation of perennating organs called tubers. These are buds in which reserve food is stored. Each tuber consists of a central part in which food is present surrounded with minute scale leaves. These develop into new plants on return of conditions favourable for growth.

Asexual Reproduction — Sporophyte

Asexual reproduction is by formation of two different types of spores, the microspores and megaspores. These are produced in separate sporangia, the microsporangia and megsporangia that are borne in specialized structures called sporocarps, developed upon short lateral branches on petioles.

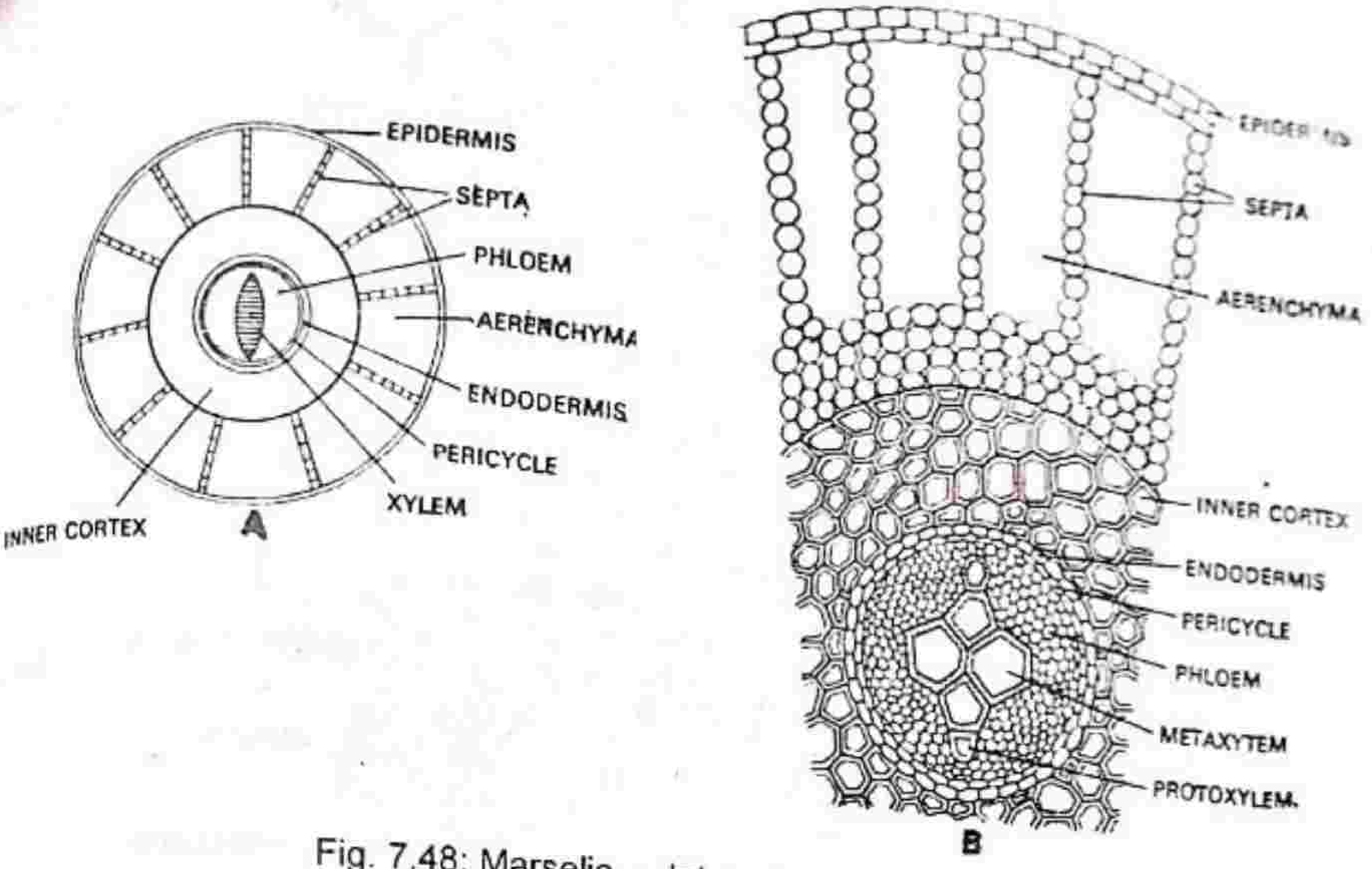


Fig. 7.48: Marselia — Internal structure of root.

The Sporocarp — Morphology and Internal Structure

Each sporocarp is bean-shaped structure attached to the petiole through a small stalk called peduncle. The young sporocarps are relatively soft and green, but they become hard, brown, and nut-like at maturity. One or more protuberances are present at the back of sporocarp near the point of attachment of peduncle. Each protuberance consists of one or two teeth or tubercles and a raphe. The raphe represents the end of the peduncle fused laterally to the back of the sporocarp. The sporocarps may be borne singly or in groups depending upon species. The thick walls of sporocarps are resistant to mechanical injury and to drying. The sporocarps protect the spores until the next wet season.

A mature sporocarp is surrounded by a thick and rigid three-layered wall consisting of the epidermis containing stomata, the hypodermis composed cells containing chloroplasts and inner wall. The epidermis is covered with cuticle. Next to inner wall a parenchymatous tissue is present whole cells gelatinize at the time of dehiscence of sporocarp and form sporophore. Each half (valve) of the sporocarp contains two rows of elongated sori, one on either side, attached to the inner wall. The sori of one row alternate with those of the other, but all are close together almost overlapping each other and fill the cavity of the sporocarp. Each sorus is surrounded by a delicate indusium. The indusia of adjacent sori are partially fused together. Both micro- and megasporangia develop in each sorus on a ridge-like receptacle. A row of megasporangia develop at the tip and many microsporangia on the sides of this receptacle.

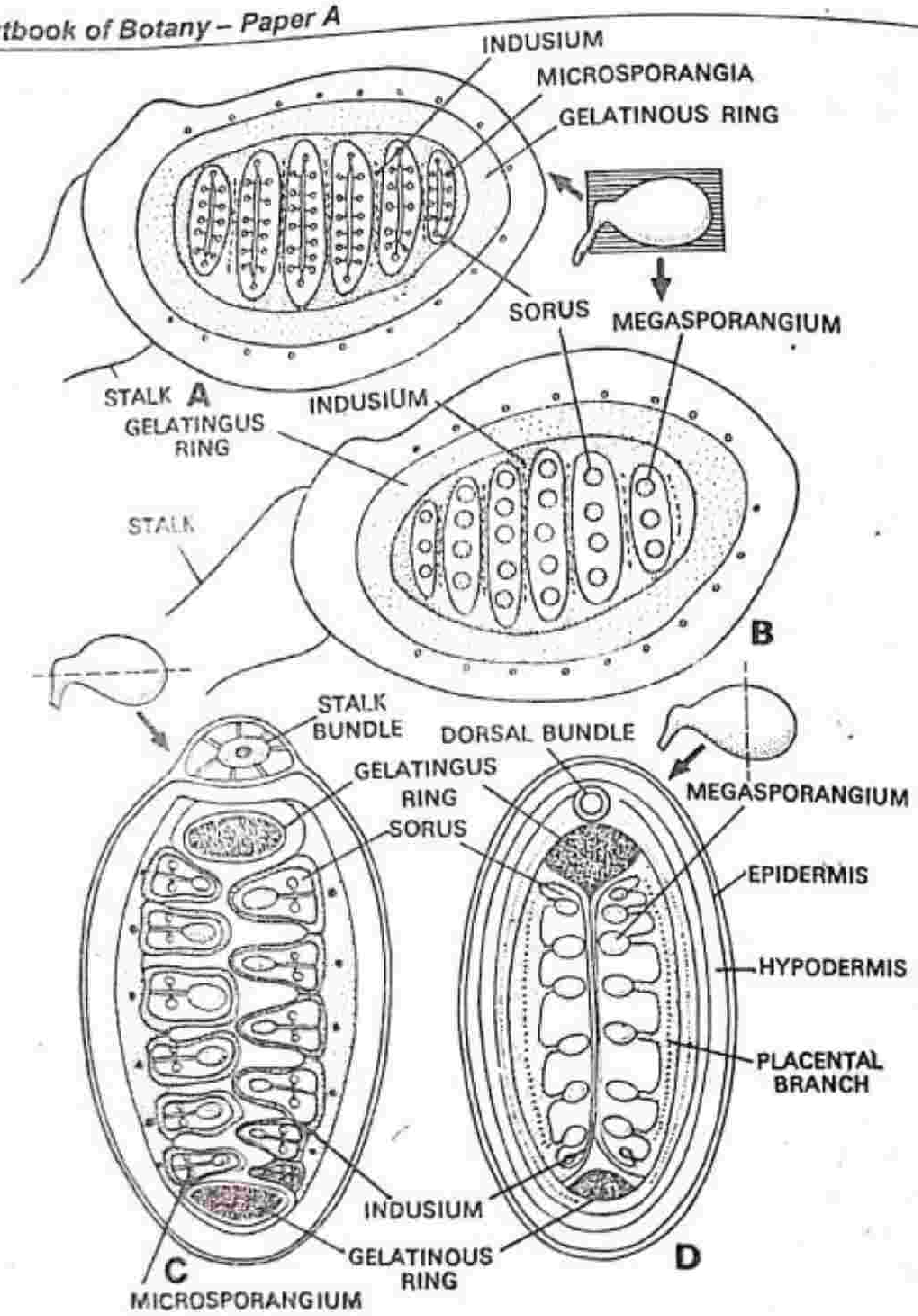


Fig. 7.49: Marselia — Internal structure of sporocarp.

Development of Sporocarp

A marginal cell of a young leaf acts as sporocarp initial. It has two cutting faces, therefore cuts off segments on either side to form a mass of undifferentiated cells. These cells get curved so that distal end become directed horizontally. This distal part enlarge to form the sporocarp. Two rows of soral mother cells appear on ventral side. These cells divide to produce derivatives. The cells surrounding the soral mother cells and their derivatives grow at faster rate so these are pushed downward and buried. A small crescent-shaped depression appears beside each sorus. It deepens and become spaces above and around the sori. These spaces are called soral canals and open to the outside through pores.

Certain superficial cells along the median line develop rows of cells that enclose the sori. These rows of cells split and separate to form indusia. The sporocarp shoulders grow and close the mouth of the soral canals. The receptacles develop from sporocarp wall. A row of sporangial initials differentiate at the apex of each receptacle. These initials develop into megasporangia. The microsporangia differentiate in basipetal succession along the sides of the receptacle.

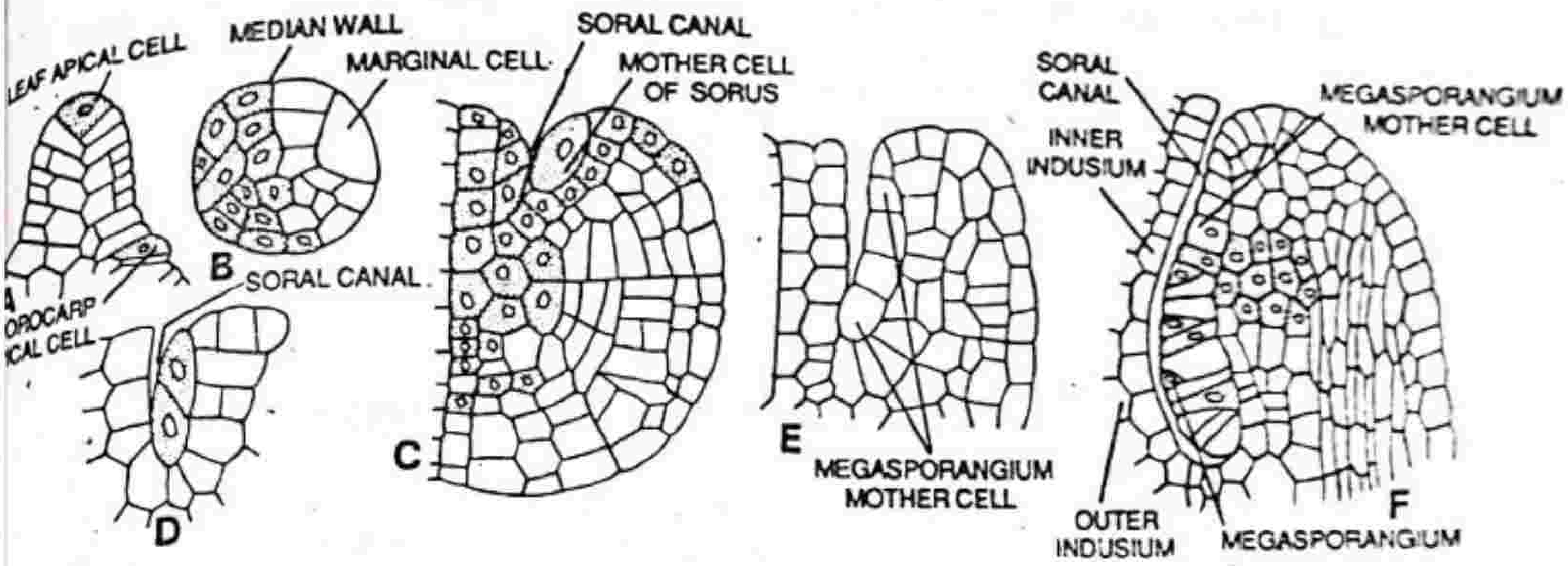


Fig. 7.50: Marselia — Development of sporocarp.

Structure and Development of Sporangia

Both microsporangium and megasporangium are stalked and each consists of a jacket layer that surrounds a nutritive layer, the tapetum, and a mass of sporogenous cells. The annulus is absent. The megasporangium contains a single large megaspore while the microsporangium contains 32-64 microspores.

The sporangial initial divides by a periclinal division to form an outer and an inner cell. The inner cell does not divide further. The outer cell divides by three diagonal walls to form an apical cell with three cutting faces. It cuts off segments that give rise to the stalk of the sporangium. The apical cell divides periclinally to form an outer jacket initial and an inner archesporial cell. The jacket initial divides by anticlinal divisions to form a single-layered jacket. The archesporial cell divides to produce tapetum and primary sporogenous cells which give rise to spore mother cells. These cells undergo meiosis to produce tetrads of spores. The sporangium contains 32-64 spores.

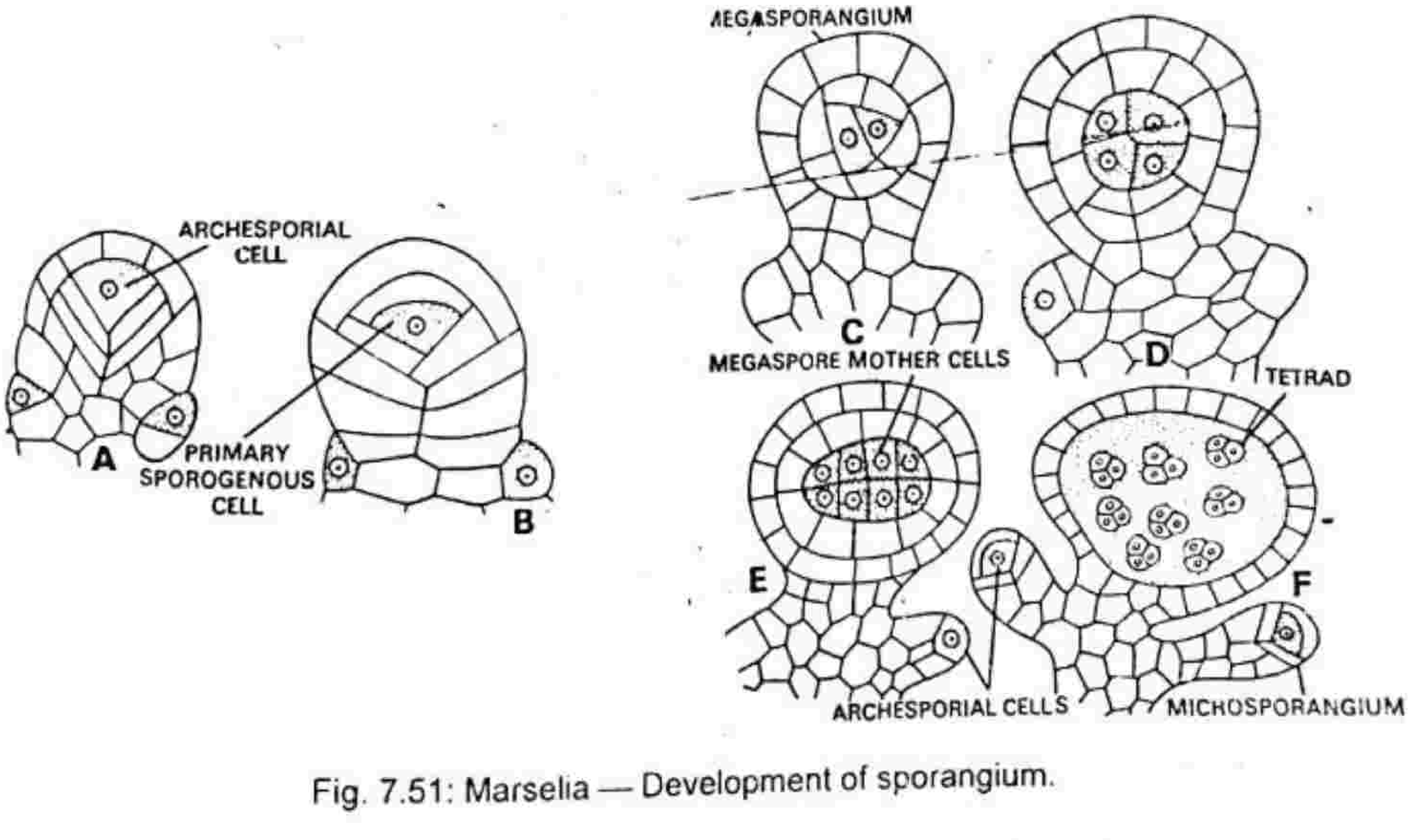


Fig. 7.51: Marselia — Development of sporangium.

Uptill this stage, the development of both megasporangium and microsporangium is alike. Later, all but one spores disintegrate and contribute to nutritive fluid, in a megasporangium. However, all the spores mature in a microsporangium.

The microspores are smaller in size and globose. Each microspore is uninucleate and contains many starch grains. The megaspore is larger in size and visible to the naked eye. It has a papilla on one side on which a triradiate ridge is present. The spore wall is many layers in thickness.

Dehiscence of Sporocarp

As the spores mature the outer layers of sporocarp wall become stony and the inner wall and receptacle except for sporangia and indusia become gelatinize to form a ring of gelatinous tissue called sorophore. The sporocarps persist in water and soil after the vegetative portions of the plants disappear. Under natural conditions the sporocarps do not open until second or third year of their formation. The bacteria help in the rotting the sporangia wall and dehiscence of sporocarp. However, the sporocarp can be opened immediately if it is placed in water after the stony layer is cut away. The gelatinous material within the sporocarp begins to swell due to imbibition of water. This swelling causes the splitting of two valves of sporocarps and these spread away from each other. The sorophore alongwith sori attached to it also move out.

A fully mature sorophore is a long gelatinous cylinder with a length of 15 to 20 times that of sporocarp. A row of sori is present of either side of the sorophore. The sori alternate with each other. The indusia and walls of sporangia also gelatinize five to six hours after liberation. The mega- and microspores are set free and start germinating into gametophytes immediately. The developing gametophytes remain embedded in the gelatinous matrix until they mature.

SEXUAL REPRODUCTION — GAMETOPHYTE

The spores germinate into gametophytes immediately after their release. The gametophytes are endosporic.

Male Gametophyte

The microspore germinates to produce male gametophyte. A mature male gametophyte consists of a prothalial cell and two antheridia in which antherozoids or male sperms develop.

Development of Male Gametophyte

The nucleus of the microspore divides and one daughter nucleus migrates to one side of the spore. A wall separates a small lens-shaped prothalial cell and a larger apical cell. The prothalial cell represents prothallus and does not divide further. The apical cell divides by a wall diagonal in plane to prothalial cell to produce two antheridial initials. Both these initials cut off first jacket cells by a curving diagonal wall. These jacket cells do not divide further. The sister cell divides periclinally to form a small inner second jacket cell and a large outer cell which divides periclinally to form the third jacket cell and primary androgonial cell. The primary androgonial cell divides by four divisions to form 16 androcytes. The androcytes metamorphose into antherozoids or male sperms. The prothalial cell disintegrate.

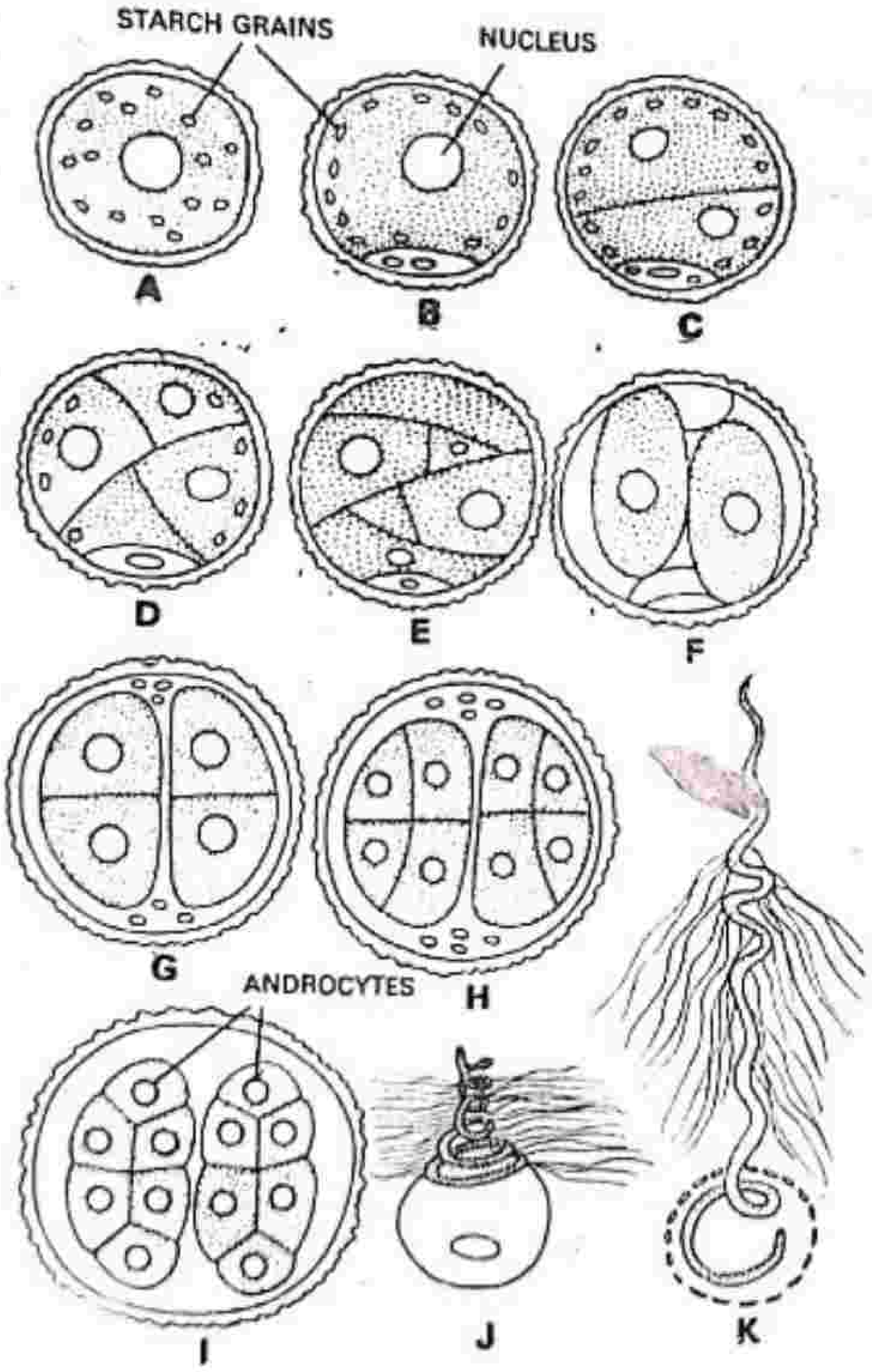


Fig. 7.52: Marselia — Development of male gametophyte.

The male sperm are cork-screw like in shape and multiflagellate with flagella attached to the broad posterior coils.

Female Gametophyte

The megaspore germinates to produce female gametophyte. The development of female gametophyte is relatively slower as compared to male gametophyte.

Development of Female Gametophyte

The female gametophyte contains a single apical flask-shaped archegnoium. The amount of granular cytoplasm at the anterior end of megaspore increases and the nucleus becomes spherical. The nucleus divides and nuclear division is followed by formation of a wall that separate the dense granular and water starch-containing cytoplasm. So an upper smaller and a lower larger cell is formed. The smaller cell lies in the papillate part of megaspore. The large cell does not divide further and act as store house of food for the developing female gametophyte. The smaller cell has four cutting faces and act as archegonial initial. But before developing into an archegonium each cutting face cuts off a segment. Repeated anticlinal divisions take place in these segments and a vegetative tissue one cell in thickness is formed.

The archegonial initial divides by a periclinal division into a primary cover cell and a central cell. The primary cover cell divides by two successive anticlinal divisions to form a tier of four neck initials. An oblique division in each neck initial results in the formation of a short neck composed of two tiers of four cells each. The central cell divides into a small lenticular primary canal cell and a large primary venter cell. The primary canal cell divides to form two small canal cells. The primary venter cell divides into a small lens-shaped venter canal cell and a large spherical egg.

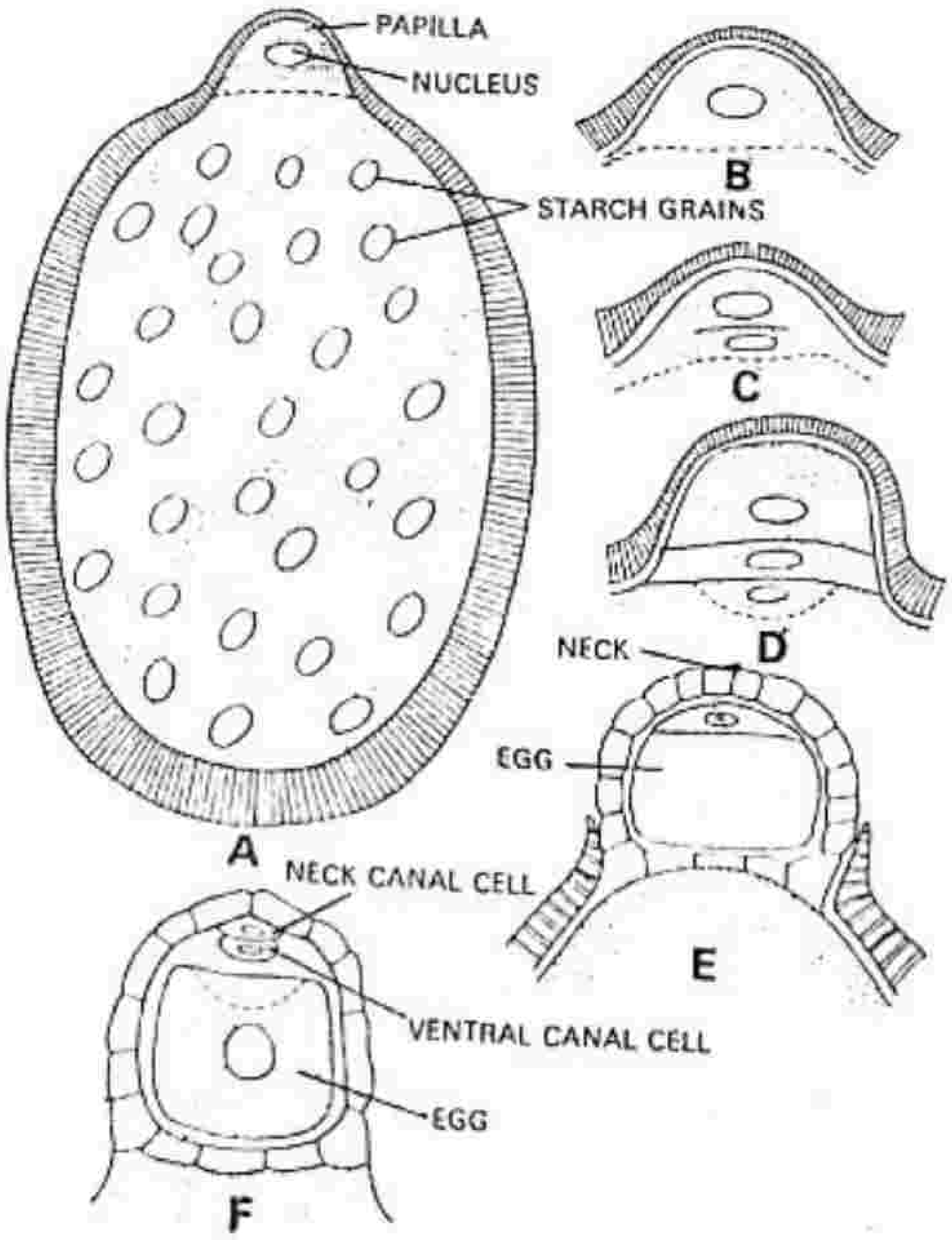


Fig. 7.53: Marselia — Development of female gametophyte.

Fertilization

The developing male gametophytes remain enclosed in the spore wall till the maturation of antherozoids. The spore wall burst and antheridia are released. The jacket cells separate and the male sperms are liberated. The neck canal cells and venter canal cell disintegrate when the archegonium is mature. The neck of the archegonium opens and pave the way for male sperms to enter it and fertilize the egg.

Many male sperms are attracted chemotactically towards the female gametophyte and swarm about the archegonial end of the gametophyte. Many of them enter the gelatinous envelope and few reach the neck of the archegonium. One of them succeeds in entering the archegonium and fertilize the egg to form the zygote.

Embryo Development

As the embryo development starts, the vegetative cells of the gametophyte are stimulated and develop a protective sheath called calyptra. The zygote starts developing into an embryo several hours after fertilization. First division of the zygote is horizontal, parallel to the long axis of the archegonium and megaspore. The second division is at right angles to the first one and result in the formation of four cells. Two upper cells form cotyledon and root and the two lower cells produce stem and foot. The cells of gametophyte facing the soil develop rhizoids. All cells of calyptra including rhizoids develop chloroplasts.

The calyptra continues to grow and keeps pace with developing embryo for the first four or five days. But, after this the cotyledon and primary root grow at the more rapid rate and burst through the calyptra to establish a new sporophyte.

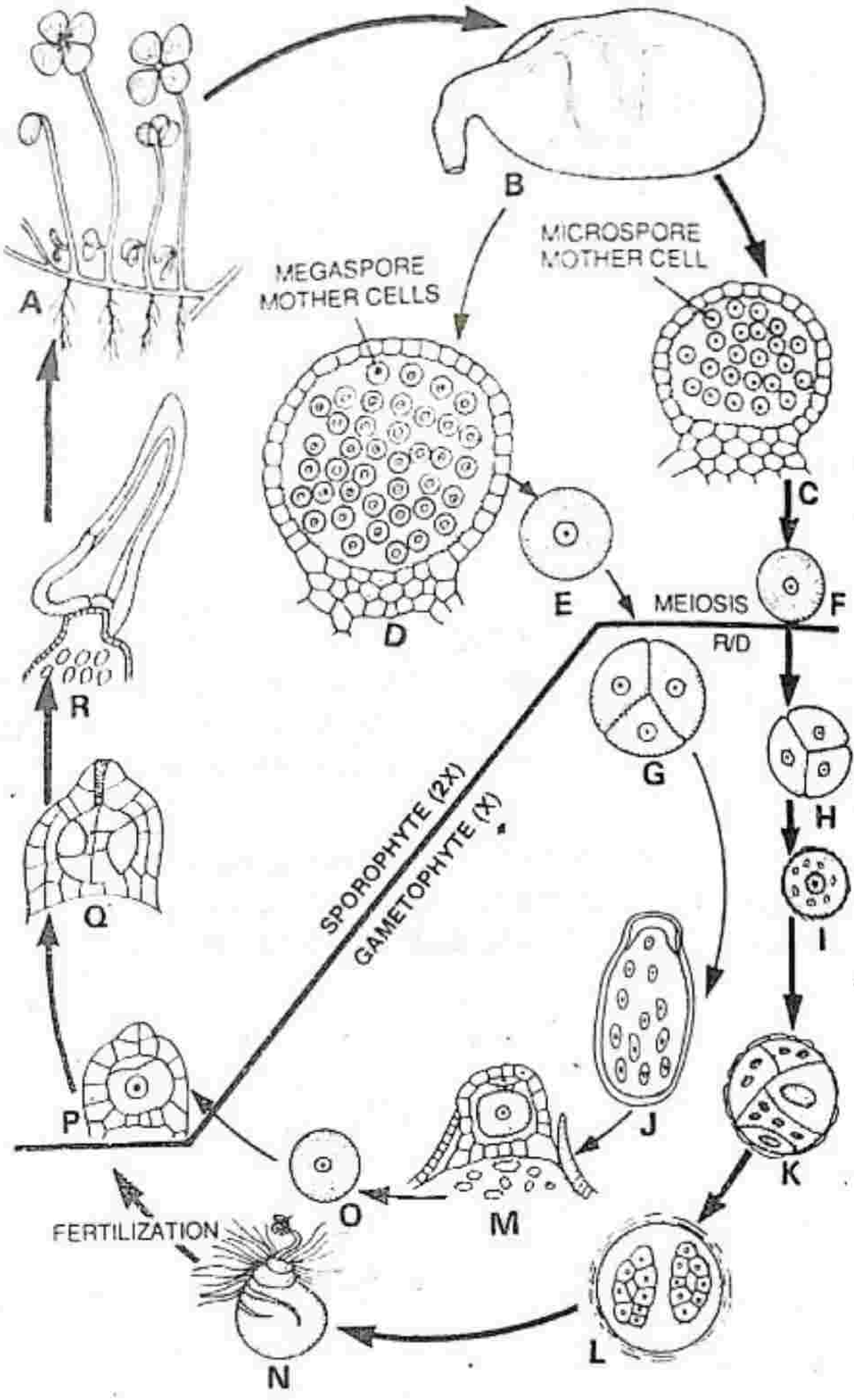


Fig. 7.54: Marselia — Life cycle.

SOME IMPORTANT QUESTIONS

Short Questions

1. What is difference of leptosporangiate ferns with normalferns.
2. What are taxonomic position of Polypodium.
3. Enlist the habitat of Marselia.
4. Which type of stele is found in Polypodium.
5. What is sporocarp.
6. What is sorus.
7. Who embryo of polypodium developed.
8. Describe embryo development in marselia.
9. Draw diagram of prothallus of polypodium.
10. Draw life cycle of Marselia.

B. Long Questions

1. Write a note on sporophyte of Polypodium.
2. Describe life cycle of Polypodium.
3. Describe gametophyte of Polypodium.
4. Describe internal structure of stem of Marselia.
5. Describe sporophyte of Marselia.
6. Write a note on sporocarp of Marselia.
7. Write note structure and development of gametophyte of Marselia.

SECTION IX

GYMNOSPERMS

Chapter 8

GYMNOSPERMS

Gymnosperms (gymnos=naked + sperma=seed) literally means naked seeds. These are the members of Spermatophyta (seed plants) in which the ovules and seeds are borne in an exposed position on the sporophylls or equivalent structures.

Gymnosperms include extremely ancient lines of seed-bearing plants and their long evolutionary history contains many examples of organisms which flourished and finally became extinct. One of the most important and interesting of these extinct gymnosperms is the group named seed ferns or Cycadofilicales. This is a group of fern-like plants with respect to their leaves and general appearance but possess a primitive type of seed. The seeds are attached to the leaves. Several other extinct groups are recognized as gymnosperms. These include Cordaitales which were dominant during Paleozoic and regarded as ancestors of Gnetales (Ephedra) and modern Coniferales (Pinus); and Bennetitales which resemble modern cycads in their vegetation and structure.

GENERAL ACCOUNT OF GYMNOSPERMS

The living gymnosperms comprise of about 70 genera and 725 species. The important characteristics vegetative and reproductive features of the gymnosperms are:

Habitat and Habit

The gymnosperms extend throughout the temperate, tropical and arctic zones. Most of these are xerophytes. The living gymnosperms include medium-sized trees (Cycas), tall trees (Pinus), and shrubs (Ephedra). The herbaceous and climbing habits are not found in gymnosperms.

Vegetative Morphology — Plant Body

The plant is a sporophyte and the plant body is differentiated into root, stem and leaves.

The Stems

The stems are aerial and erect. In Cycas the stemisunbranched whereas in *Pinus, Taxus and Ephedra* the stem is branched. The vascular bundles of the stem are collateral, endarch and open. These are arranged in a ring.In Ephedra the stem is green, hard, ribbed, glabrous and much branched. It has jointed long internodes. The branches are green and photosynthetic.

The Leaves

Two types of leaves are found in gymnosperms:

i. Microphyllous Leaves:

These are smaller in size and scale-like leaves, for example those found in Ephedra.

ii. Megaphyllous Leaves:

These are large and well developed leaves, for example those present in Cycas and Pinus. These are foliage leaves and are protected by thick layers of cuticle and sometimes by an additional waxy layer.

The leaves may be simple or compound (Cycas) and vary in size from minute scale leaves to large megaphylls. The megaphylls of cycads may reach a length of six feet. The leaves show reticulate, parallel or dichotomous type of venation. The arrangement of leaves may be opposite and decussate (Ephedra), whorled (Cycas) or spiral (Taxus). The leaves of Pinus are needle-like and are usually called pine needles. Similarly the leaves may be bifacial (Cycas leaflets), triangular (pine needles) or circular (Pinusmonophylla).

The Roots

The roots are tap roots generally but in some genera, e. g., in Cycas and Pinus coralloid roots and mycorrhizal roots are found. These roots help in absorption of water and minerals and provide mechanical support to the plants.

Secondary Growth

The gymnosperms exhibit well marked secondary growth that results in the formation of secondary xylem and secondary phloem. The secondary growth is brought about by vascular cambium. Distinct annual rings are produced during secondary growth. The wood produced during secondary growth is commonly termed as secondary wood.

In Pinus and Taxus the cambium is very active therefore pith and cortex are both very reduced resulting in the formation of dense and packed wood.

The xylem is without vessels except for in Ephedra, and usually mesarch or endarch. The tracheids in the secondary wood have bordered pits usually but tracheids with scalariform wall thickening are also found. The xylem rays may be uniseriate or multiseriate. The phloem is without companion cells.

Reproduction

The gymnosperms reproduce by asexual and sexual modes of reproduction usually. The vegetative propagation is absent in gymnosperms, however Cycas reproduces vegetatively by forming bulbil-like structures.

Asexual Reproduction

The gymnosperms are heterosporous, i.e., they produce two types of spores, the microspores and megaspores. In certain cycads the microspores may actually be larger than the megaspores and in other gymnosperms these are of equal size approximately. Therefore, the terms pollen spore and seed spore were suggested to replace the terms microspore and megaspore. Both the microspores and megaspores are haploid and are first cells of their respective gametophytes.

Sporangia

The microspores are produced in microsporangia. These develop into male gametophytes. The megaspore arise deep in the nucellus tissue contained in the ovule. Usually a single megaspore survives which develops into female gametophyte. Two or more female sex organs called archegonia develop in the female gametophyte.

Sporophylls

The sporangia are borne on sporophylls. The sporophylls bearing microsporangia are called microsporophylls whereas those bearing megasporangia or ovules are known as megasporophylls. The sporophylls are arranged spirally along a main axis to form a loose or compact cone or strobilus. The strobili bearing microsporophylls are called microsporangiate or male strobili, whereas those bearing megasporophylls are known as megasporangiate or female strobili. Both the male and female strobili may be present on the same tree as in Pinus or on different trees as in Cycas.

Male Strobili

The male strobili or the cones are of varying size and shape. Similarly their position on the plant also varies. Generally each strobilus consists of a main axis upon which the microsporangia-bearing leaves called sporophylls are arranged.

Microspores

Microspores are unicellular and haploid. The microspore wall is double-layered. The outer wall is called exine whereas the inner wall is termed intine. One to many apertures are present in the wall of the microspores.

Female Strobili

The female strobili or cones like the male strobili show variations in size, shape and their position on the plant. Generally a female strobilus comprises of a main axis upon which megasporophylls are arranged. The ovules develop on these megasporophylls.

Sexual Reproduction

The microspores and megaspores develop into male gametophytes and female gametophytes respectively. The gametophytes in gymnosperms are endosporic, i.e., they start their development within their respective sporangia. The female gametophyte is retained by the megasporangium or ovule.

Microgametophyte or Male Gametophyte

The male gametophytes are endosporic. They complete their development partly in the microsporangium and partly in the pollen chamber of the ovule. A male gametophyte generally consists of prothalial cells, generative cell and tube cell. The intine of the microspore protrude out into a long tube-like structure called pollen tube. It carries the male gametes to the egg present in the female gametophyte.

Megagametophyte or Female Gametophyte

The functional megaspore enlarges in size and undergoes free nuclear divisions i.e., the divisions not accompanied with wall formation, so that a large number of nuclei are formed. The wall formation starts at periphery and proceeds towards the center until entire gametophyte becomes cellular. The cells of female gametophyte become richly stored with reserve food materials. The ovule wall increase in thickness. Certain superficial cells, those near the micropylar end give rise to archegonia.

Archegonia

The number of archegonia varies usually from two in and Cycas to many as in many conifers. Each archegonium consists of two parts: an upper short or long neck made of two (Cycas), four (Taxus) or eight tiers of four cells each (Ephedra); and a basal swollen venter which contains a large egg or ovum and ventral canal cell.

Pollination

The ovules in gymnosperms are naked, therefore the pollination consists of transfer of partly developed endosporic male gametophyte to the micropylar end of the ovule. This is usually brought about by wind and in some cases by animals. In many gymnosperms the microspore wall adheres to a drop of sticky fluid which exudes from the micropyle of the ovule. This is called pollination drop. When this liquid begins to dry it retracts drawing the male gametophyte down into the ovule. This is followed by closure of the micropyle.

Formation of Pollen Tubes and Fertilization

In the ovules of Paleozoic gymnosperms, well developed pollen chambers were present at the free apical end of the nucellus. These chambers contained liquid in which flagellated sperms were liberated by the dehiscence of microsporangium wall. These pollen chambers are found in Ginkgo, Cycas and Ephedra among the living gymnosperms. In Pinus these are absent and endosporic male gametophytes comes in direct contact with the surface of the nucellar beak.

In living gymnosperms the male gametophytes produce a tubular outgrowth called pollen tube. It is usually extension of the inner wall, the exine through the aperture. At the time of fertilization the basal end of the pollen tube bursts liberating the two flagellated sperms above the female gametophyte. One or both sperms may enter an archegonium and one of them fertilize the egg. It grows down into the nucellar tissue, enter the archegonium and releases the non-motile sperms directly into it. The pollen tube carries the sperms to the egg cell.

Embryogeny— Embryo Formation

The embryo formation is by free nuclear division in living gymnosperms, a unique characteristics not found in lower vascular plants and angiosperms. After the nuclear division the wall formation starts and the embryo becomes cellular. Later on the embryo differentiates into a suspensor, radicle, hypocotyl, plumule and cotyledons. The shoot end of the embryo develops away from the micropyle. After development of embryo the nucellar tissue of the ovule becomes disorganized and usually persists only as a paper-like cap of dry tissue at the micropylar end of the seed. The various layers of integument undergo maturation and the stony layer becomes extremely hard, resistant shell which encloses and mechanically protects the female gametophyte and the embryo.

Polyembryony

Polyembryony, i.e., the formation of several embryos in a single gametophyte is common in gymnosperms. This is possible because more than one archegonium is commonly fertilized, and hence several zygotes may be produced. But most remarkable is the process of cleavage polyembryony, which is characteristics of a majority of conifers. In this process certain cells of the young embryo becomes separated from one another and give rise to a system of four or more distinct embryos. Physiological competition between the various embryos usually results in the elimination of all but one embryo, which continues its differentiation and becomes the dominant embryo in the fully developed seed.

Seed Formation

The stimulus of fertilization brings changes in the ovule and it matures into a seed. The zygote develops into an embryo, the endosperm persists as nutritive tissue and the nucellus is disorganized. In some cases the nucellus persists as dry tissue at the micropylar end of the seed and form a cap-like structure called nucellar cap in the mature seed. The inner fleshy layer of the ovule may persist as thin layer of the seed coat and is called tegmen. The middle stony layer differentiates into protective layer known as testa. The outer fleshy layer of the ovule develop into scarlet red, fleshy covering around the seed in Cycas and Taxus. It becomes free from the testa and develops stomata, fibres and sclereids. In Taxus a fleshy structure called aril develops from the base of the seed.

The seeds of all gymnosperms except Cycas and Ginkgo remain dormant for sometime before germination. The germination of the seed is epigeal, i.e., the cotyledons come above the ground during germination.

ECONOMIC IMPORTANCE OF GYMNOSPERMS

Gymnosperms are of immense importance in nature and man's economy. Their common uses are as followings.

i.Source of Timber

Conifers are best and most economic source of timber and constitute major forest wealth of the country. The wood produced by conifers is strong, durable and is used in making furniture, doors, railway sleepers, boats, storage vats, etc. *Cedrusdeodara* (deodar) wood is strongly resistant to fungus and insect attacks. Pinusspp (chir) yield light timber used for ship making and heavy construction work.

ii.Source of Resins

Resins are plant exudates secreted in specialized canals or ducts. They are insoluble in water and soluble in organic solvents and are used in varnishes, paints, lacquers, medicines and in paper sizing. The major source of resins are conifers. The most common of these are Rosin, Canada Balsom etc.

iii.Source of Essential oils

Various kinds of essential oils are obtained from different conifer species. *Abiessachaliensis* produces Japanese pine need oil used in making scentred soaps. Oil obtained from *Cedrusatlantica* and *Cedrusdeodara*are used in perfurmary. Turpentine oil obtained from Pinusspp is used as solvent, in making paints and varnished, as thinner, etc.

iv.Source of Fatty Oils

The seeds of *Macrozamia, Torreya and Pinus* species are source of fatty oils used as food.

v.Usage in Paper Industry

Wood pulp of some species such as *Piceasmithiana, Pinusroxburghii, Abiespindrow.*etc is used in paper making. Most of the newspaper is made from Pinus pulp.

vi.Source of Medicines

Most gymnosperm species possess medicinal value, the Ephedra is perhaps the most important. It is source of ephedrine used to cure asthama, hay fever, and bronchial troubles. Similarly the *Taxusbaccata* leaves are used in curing asthama, bronchites, hie cough, and epilepsy.

vii.Source of Food

Most gymnosperms afford as source of food for human beings. The stem and seeds of Cycas yield sago or arrowroot. The seeds of *Dioonedule* are used for bread making. Seeds of *Pinusgerardiana*(chilghoza) are edible and are rich source of fats. Young leaves and strobili of Gnetumgnemon are cooked as vegetable.

viii.Ornamentals

Several gymnosperm species are grown as ornamentals in gardens and for decorative purposes. The most common being *Cycas. Ginkgo*, commonly called *Maidenhair* tree, is grown as ornamental in temples in China and Japan and is worshipped. Juniperous, Thuja and Botaspp are cultivated as ornamental trees in plains. Some species of Gnetum and Ephedra are also grown as ornamentals.

AFFINITIES OF GYMNOSPERMS

Evolutionary tendencies reveal that gymnosperms form a bridge between pteriodphytes and angiosperms. They resemble pteridophytes on one hand and angiosperms on the other hand. Eames placed gymnosperms between Filicineae and Angiospermae under Pteropsida, a sub-division of Tracheophyta. But later these were segregated as an independent group.

Affinities with Pteriodphytes

The gymnosperms resemble pteridophytes in several features. Such as:

i. Both possess dominant, independent sporophytes that are differentiated into root, stem and leaves. The leaves in pteridophytes and gymnosperms are megaphyllous. The venation in Ginkgo is dichotomous as in pteridophytes.

ii. The sporophyte contains a well developed vascular system in both the groups. The xylem lacks vessels and phloem is without companion cells in both cases except in Ephedra.

iii. Most pteridophytes such as Selaginella, Marselia, Isoetes, etc are heterosporous like gymnosperms.

iv. Many cycads resemble ferns in possessing large compound leaves and in circinateptyxis of the leaves. Extinct seed ferns (Cycadofilicales) were much like present-day pteridophyte ferns.

v. The gametophytes in both pteridophytes and gymnosperms are endosporic and highly reduced. The male gametophyte consists of two prothalial cell only in some gymnosperms. The male gametes in Cycas and Ginkgo are motile like the pteridophytes. The female gametophyte develops by free nuclear division.

vi. Endosperm develops before fertilization in both groups. Embryogeny is endoscopic in many pteridophytes and most gymnosperms.

vii. The life cycle of both pteridophytes and gymnosperms are characterized by presence of heteromorphic alternation of generations.

However, gymnosperms differ from pteridophytes in follwoing respects:

i. The gymnosperms are trees or shrubs usually whereas the living pteridophytes are herbaceous.

ii. The gymnosperms exhibit secondary growth while it is absent in pteridophytes except for in Isoetes.

iii. The stele in gymnosperms is eustele whereas it is protostele to siphonostele in pteridophytes.

iv. The megaspore is retained within the megasporangium in case of gymnosperms while in heterosporous pteridophytes it is shed.

v. The male gametes are transported through pollen tubes in gymnosperms.

vi. Seed formation is common in gymnosperms.

Affinities with Angiosperms

The common features between gymnosperms and angiosperms are:

i. The dominant generation in both groups is sporophyte which is differentiated into root, stem and leaves.

ii. In both groups, the root system is well developed and exhibit secondary growth. The roots are diarch to polyarch. The xylem is exarch.

iii. Both are heterosporous and produce seeds.

iv. The nucellus (megasporangium) in gymnosperm and angiosperms is surrounded by integument and form ovule. The ovule matures into a seed.

v. The megaspore is retained within the megasporangium which remains attached to the female gametophyte in gymnosperms as well as angiosperms.

vi. The germination of gametophytes is endosporic and the gametophytes are reduced very much in both groups.

vii. Pollination results in transfer of semi-germinated microspore to the female gametophyte in both groups.

viii. The male gametes are non-motile and the pollen tubes carry male gametes to female gametes in both gymnosperms and angiosperms.

vii. The life cycle of both gymnosperms and angiosperms are characterized by presence of alternation of generations.

The gymnosperms differ from angiosperms in the following respects:

i. The gymnosperms lack herbaceous habit whereas most angiosperms are herbs. Similarly gymnosperms are perennials while the angiosperms may be annuals, biennials or perennials.

ii. The gymnosperms lack vessels except in Ephedra and companion cells.

iii. Vegetative reproduction is absent in gymnosperms except in Cycas.

iv. Flower formation is absent in gymnosperms. The reproductive organs are strobili.

v. Pollination in gymnosperms is by wind only which resulted in their restriction to particular habitat only.

vi. Prothalial cells are present in male gametophytes in gymnosperms while these are absent in angiosperms.

vii. The ovules are naked in gymnosperms whereas in angiosperms these are enclosed in ovary.

viii. Double fertilization is absent in gymnosperms and the endosperm is continuation of the female gametophyte.

ix. Gymnosperms exhibit cleavage polyembryony while the angiosperms lack it.

CLASSIFICATION OF GYMNOSPERMS

David Bierhorst (1971) classified gymnosperms into three classes: Cycadopsida that includes Cycadales, Coniferopsida containing Ginkgoales, Coniferales and Taxales, and Gnetopsida comprising of Ephedrales, Gnetales and Welwitschiales.

OUTLINE OF CLASSIFICATION FOLLOWED IN THE BOOK

Division I:Cycadophyta

The division includes both extinct and extant gymnospermous seed plants with fernlike foliage. Three classes are recognized in the division:

Class 1: **Pteridospermopsida:**The class includes extinct seed ferns.

Class 2: **Cycadeoidopsida:**The class also include fossil members.

Class 3: **Cycadopsida:**The class includes fossil members and a single order Cycadales with living genera like Cycas, Zamia, Microcycas, Dioon, etc.

Division II:Ginkgophyta

The division includes a single class: Ginkgopsida with a single genus: Ginkgo placed in order: Ginkgoales and family: Ginkgoaceae.

Division III:Coniferophyta

The division includes three classes.

Class 1: **Cordaitopsida:**The class comprises of extinct plants and represented by fossils.

Class 2: **Coniferopsida:**The class is represented by some 50 genera and 550 species. Among these are familiar trees such as Tsuga (hemlock), Abies (fir), Picea (Spruce), Juniperus (juniper, red cedar), Sequoiadendron (Sierra redwood), etc. Pinus and its relatives are the dominant type of the forests.

Class 3: **Taxopsida:**The class include taxads in which female strobilus is absent and the ovules develop at the ends of short lateral branches. Taxus and Torreya are representative genera of the class.

Division IV:Gnetophyta

The division comprises of class: Gentopsida with three orders: Ephedrales, Gnetales, and Welwitschiales. The Ephedra, Gnetum and Welwitschia are the representative genera.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are gymnosperms.
2. What is secondary growth.
3. What are male and female strobili.
4. How pollination in gymnosperms takes place.
5. Define fertilization and give process of fertilization in gymnosperms.
6. What is female gametophyte.
7. Define polyembrony.
8. Enlist source of essential oil found in gymnosperms.
9. Name ornamental gymnosperms.
10. Enlist source of medicines of gymnosperms.

B. Long Questions

1. Write general character of gymnosperms.
2. Describe economic importance of gymnosperms.
3. Write note on affinities of gymnosperms.

CYCADOPHYTA

General Characters

1. The Cycadophyta include both extinct and living gymnosperms with fern-like foliage.
2. They were a flourishing group of plants during Mesozoic period but many of the members become extinct and now this group is represented by only nine living genera. They distributed in tropical and subtropical regions.
3. The plants are Palm like in habit having an unbranched stem with a crown of large pinnate compound leaves at top.
4. The leaves show circinate vernation in bud condition.
5. The stem is covered by persistent leaf bases.
6. The growth of these plants are very slow.

CYCAS

Cycas (Gr. kykos=a palm) is commonly found in tropical and sub-tropical regions of the world. *Cycas revoluta*(sago palm) is most common and widely studied species in the sub-continent. It is cultivated for yield of starch-rich sago used as food. *Cycas circinalis* is cultivated as ornamental for its large attractive palm-like leaves.

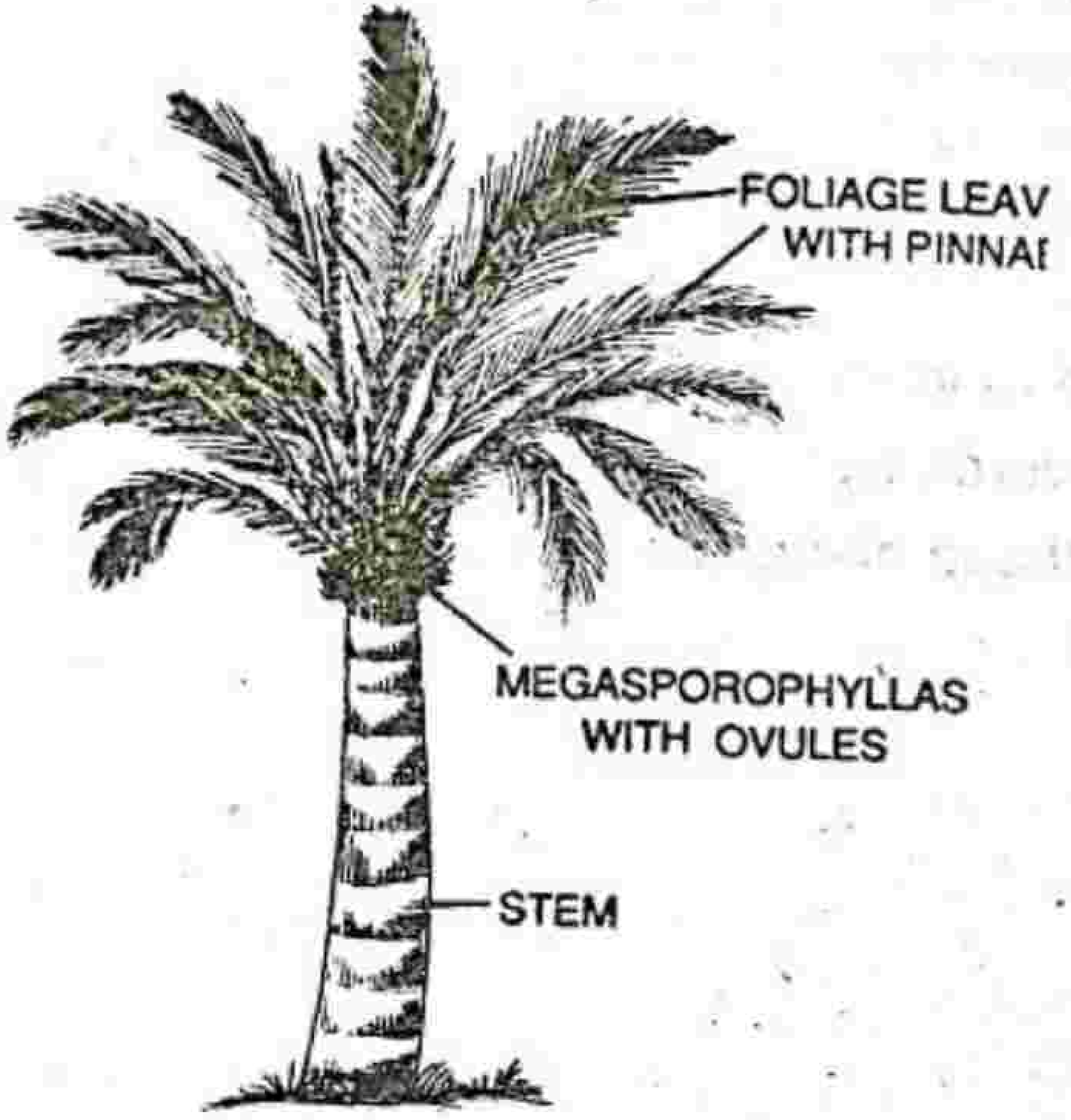


Fig. 8.1: A plant body.

External Morphology

The *cycas* exhibit the following charactristics

1. *Cycas* is a heterosporous sporophyte.
2. The plant body consists of a short, tuberous, unbranched stem which bears a crown of large fern-like leaves.
3. The stem is covered with tough leaf bases.
4. In some species large adventitious buds called bulbils develop on the basal part of the stem. They contain reserve food and serve the purpose of vegetative reproduction.
5. The leaves are pinnately compound and exhibit circinate vernation. Each pinna has a narrow outline and a single midvein. A new crown of leaves appear at an interval of two to three years and each crown remains on the stem for many years. The leaf bases persist after leaf fall and form a protective covering. The leaves are covered and protected with bud scales.
6. The root is primary which give rise to short lateral branches. Some of these branch roots are infected with blue-green alga Anabaena. These branches grow horizontally on and above the surface of the ground.
7. They branch dichotomously and form a coral-like mass, therefor called coralloid roots.

INTERNAL ANATOMY

The Root

The anatomy of primary root is similar to that of a dicot root.

Epiblema

The outermost layer is root is epiblema or pilifeous layer. It is single layered and surrounds the cortex.

Cortex

The cortex is composed of parenchyma cells and the cells of the innermost layer of cortex are four-sided and slightly elongated longitudinally. This layer is designated as endodermis.

Stele

The stele is diarch in young roots and tetrarch in older parts.

Pericycle

The boundary of the stele is occupied by a single layered pericycle composed of parenchyma cells.

Xylem& Phloem

The xylem bundles are exarch with protoxylem towards the outside and metaxylem towards the center. The number of phloem bundles is equivalent to xylem bundles and these alternate with protoxylem elements. The metaxylem elements may fuse or meet in the center. Pith is present in the young roots but it disappears later on. The root tip is protected by root cap.

Secondary growth takes place in older regions of the primary root. The secondary vascular bundles are arranged in concentric rings. The periderm replaces the epiblema and cork develops on the outer side of the root.

Coralloid Root

The internal structure of the coralloid roots is similar to that of primary root and the only difference is that a conspicuous broad algal zone is present in the middle of the cortex. Thus, the cortex can be differentiated into three regions, the outer cortex, middle cortex infected with a blue-green alga Anabaena, and inner cortex.

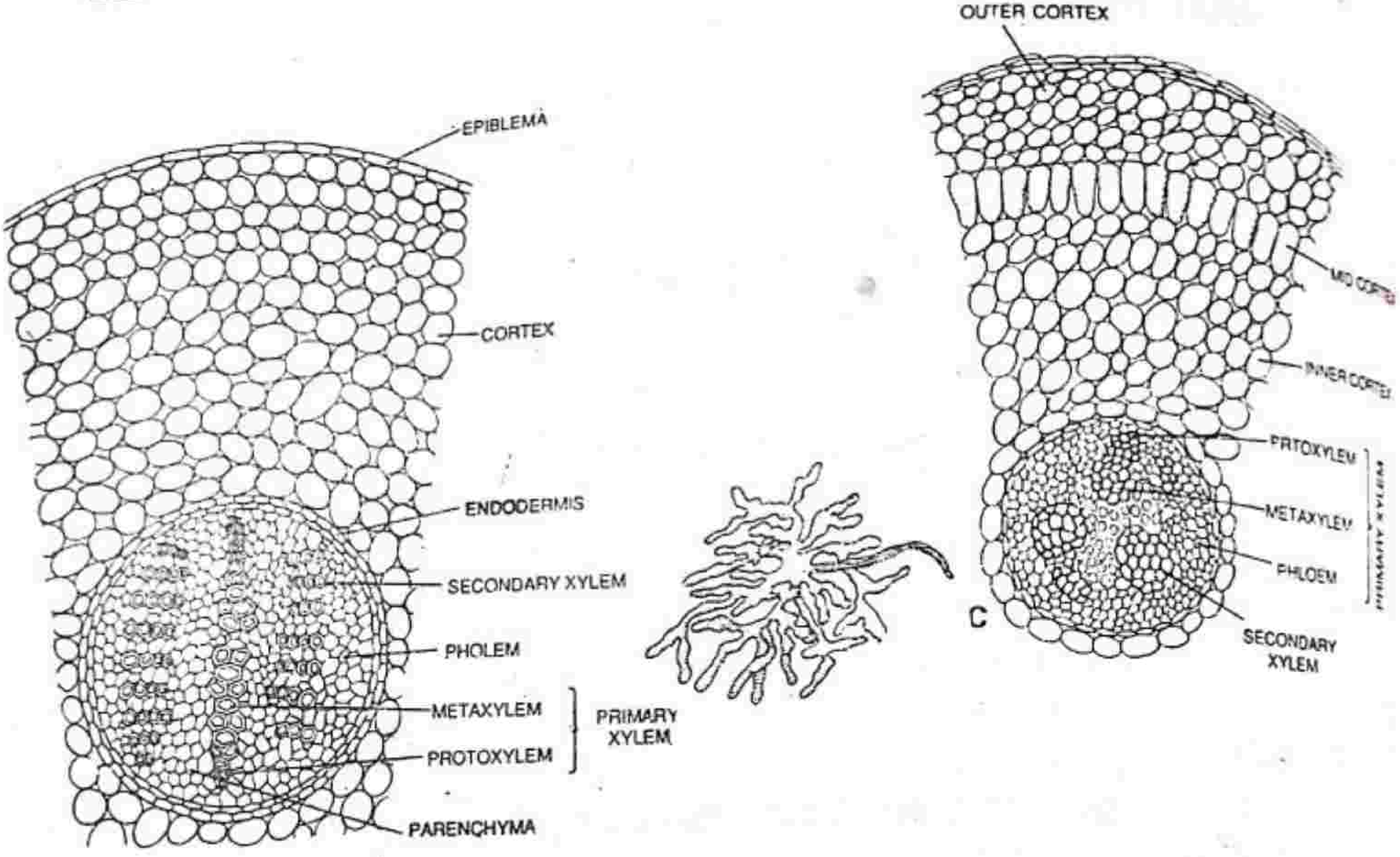


Fig. 8.2: Cycas — Internal structure of root

THE STEM

The stem appears irregular in outline in a transverse section due to presence of persistent leaf bases.

Epidermis

The outermost protective layer is epidermis. It is single layered and discontinuous due to interruption at places by the persistent leaf bases.

Cortex

Beneath the epidermis a broad cortex is present. It comprises of thin-walled parenchyma cells which are filled with starch in old stems. Mucilage canals are found in the cortex.

Stele

The endodermis and pericycle are not distinct. Many vascular bundles arranged in ring are present in the stem. These are conjoint, open, collateral and endarch.

Xylem & Phloem

The xylem consists of tracheids and xylem parenchyma and the phloem is composed of sieve tubes and phloem parenchyma cells. The vessels and companion cells are absent. The vascular bundles are separated by broad and deep medullary rays.

The center of the stem is occupied by a very large pith consisting of parenchyma cells rich in starch. Many mucilage canals are present in the pith.

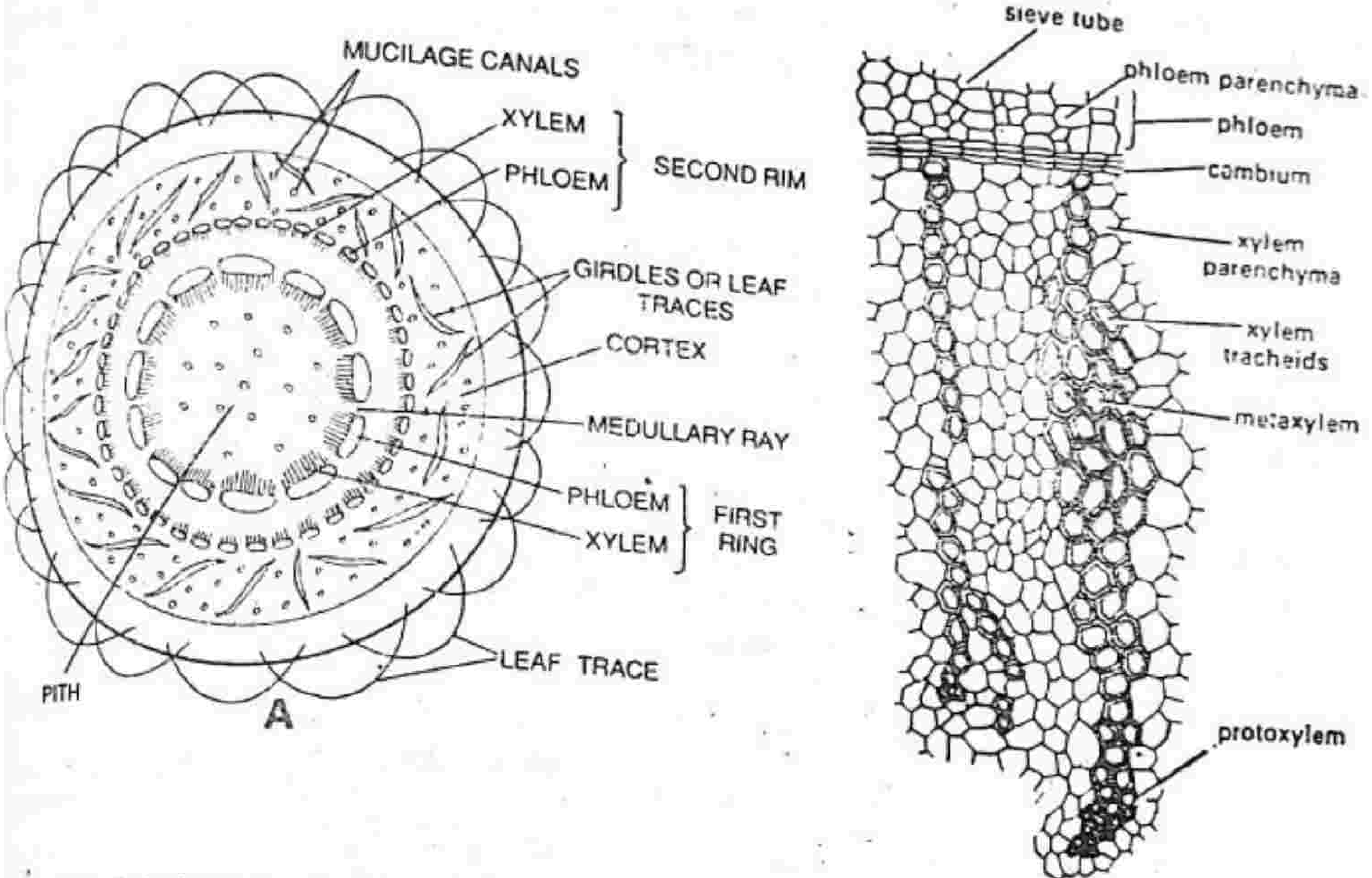


Fig. 8.3: Cycas — A. Internal structure of stem; B. Section through a vascular bundle.

Secondary Growth in Stem

Secondary growth is by the activity of vascular cambium. The fascicular and interfascicularcambium join to form cambial ring. The cells of cambial ring cut off secondary xylem towards the inner and secondary phloem towards the outer side of the vascular bundles, and cells of secondary medullary rays in between the vascular bundles. The secondary tissue is produced at slower rate therefore the amount of secondary tissue is small. The primary cambial ring dies after some time and a new cambial ring arise outside the secondary phloem. It produces second concentric ring of wood and paves the way for the third cambial ring. The successive cambial rings are derived from the cells of preceding cambial rings. Thus, several rings of secondary wood are produced during the secondary growth in stem. As increase in girth takes place, the epidermis ruptures and is replaced by periderm. It originates from phellogen or cork cambium produced by activity of the cells of the cortex present beneath the epidermis.

LEAFLET ANATOMY

Epidermis

A section through a leaflet in midrib region reveals that the upper and lower surfaces of the leaf is bounded by epidermis. It is a single layer of thick-walled parenchyma cells. The lower epidermis contains sunken stomata. The upper epidermis is covered with cuticle. Beneath the epidermal surfaces there is a single layer of thick-walled cells forming hypodermis which encloses mesophyll tissue.

Mesophyll

The mesophyll is differentiated into palisade layer present below the upper hypodermis. They contain elongated columnar cells with chloroplasts. The spongy mesophyll present above the lower hypodermis and comprises of loosely arranged parenchyma cells.

Transfusion Tissues

On either side of the midrib, between the palisade and spongy mesophyll, there is a zone of thick-walled, elongated, colourless cells running parallel to the leaf surface. It is accessory transfusion tissue.

Vascular Bundle

The center of the leaflet occupied by vascular bundle. It consists of xylem facing the upper surface and phloem facing the lower surface. The xylem consists of a mass of tracheids and phloem is formed of sieve tubes and phloem parenchyma. On the sides of xylem mass there is primary transfusion tissue composed of tracheidal cells. It is connected to accessory transfusion tissue.

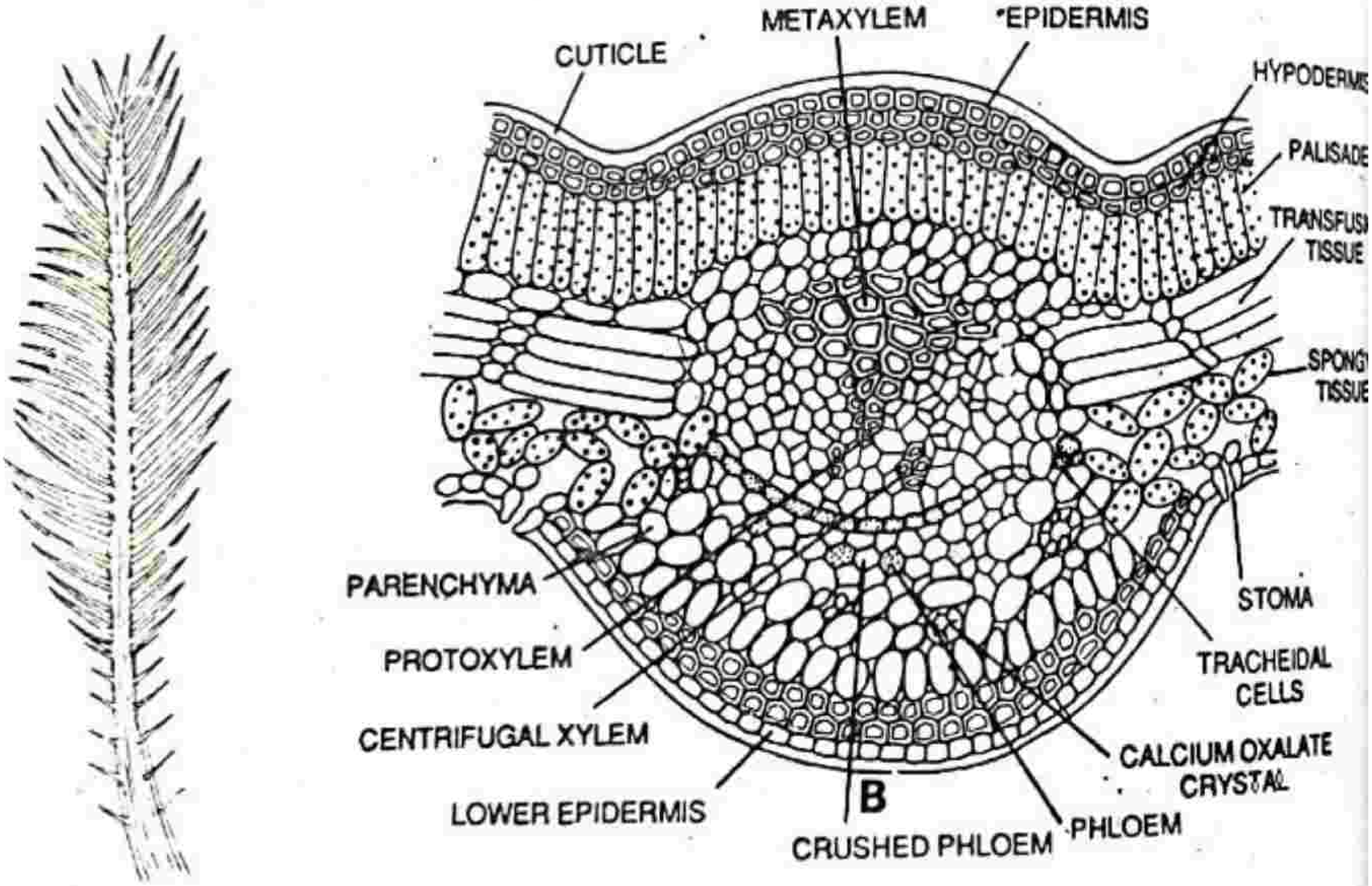


Fig. 8.4: Cycas — A leaflet and its internal structure.

LIFE CYCLE — Reproduction

The reproduction in *Cycas* is vegetative and sexual.

Vegetative Reproduction

Cycas reproduces vegetatively by formation of adventitious buds containing reserve food, the bulbils. These develop on the basal part of the stem in the axils of scales. Each bulbil consists of a few scales and foliage leaves. It develops into new plant upon detachment.

Sexual Reproduction

Cycas is dioecious, i.e., male and female plants are separate. However, the male plants are very rare. The plant is heterosporous and produces two kinds of spores, the microspores which develop into male gametophytes and megaspores that develop into female gametophytes. The spores are produced in separate sporangia that develop on scale-like structures, the sporophylls. The sporophylls aggregate to form strobili or cones. The male and female cones are produced on separate plants.

Male Cone

The male cones of *Cycas* are largest among the male cones in gymnosperms. Usually a single, woody, spindle-shaped male cone about 50 cm in length develops at the apex of the stem. Each cone comprises of a central axis to which spirally arranged woody microsporophylls are attached. Each microsporophyll is wedge-shaped, i.e. it consists of a narrow lower part and a broad upper part which is modified into a flat, sterile disc, the apophysis. Several hundred microsporangia are borne on the abaxial surface of the microsporophyll. These are arranged in soral clusters. Each sorus contains 2-6 sporangia. The sporophylls at the apex and base of the cone remain sterile.

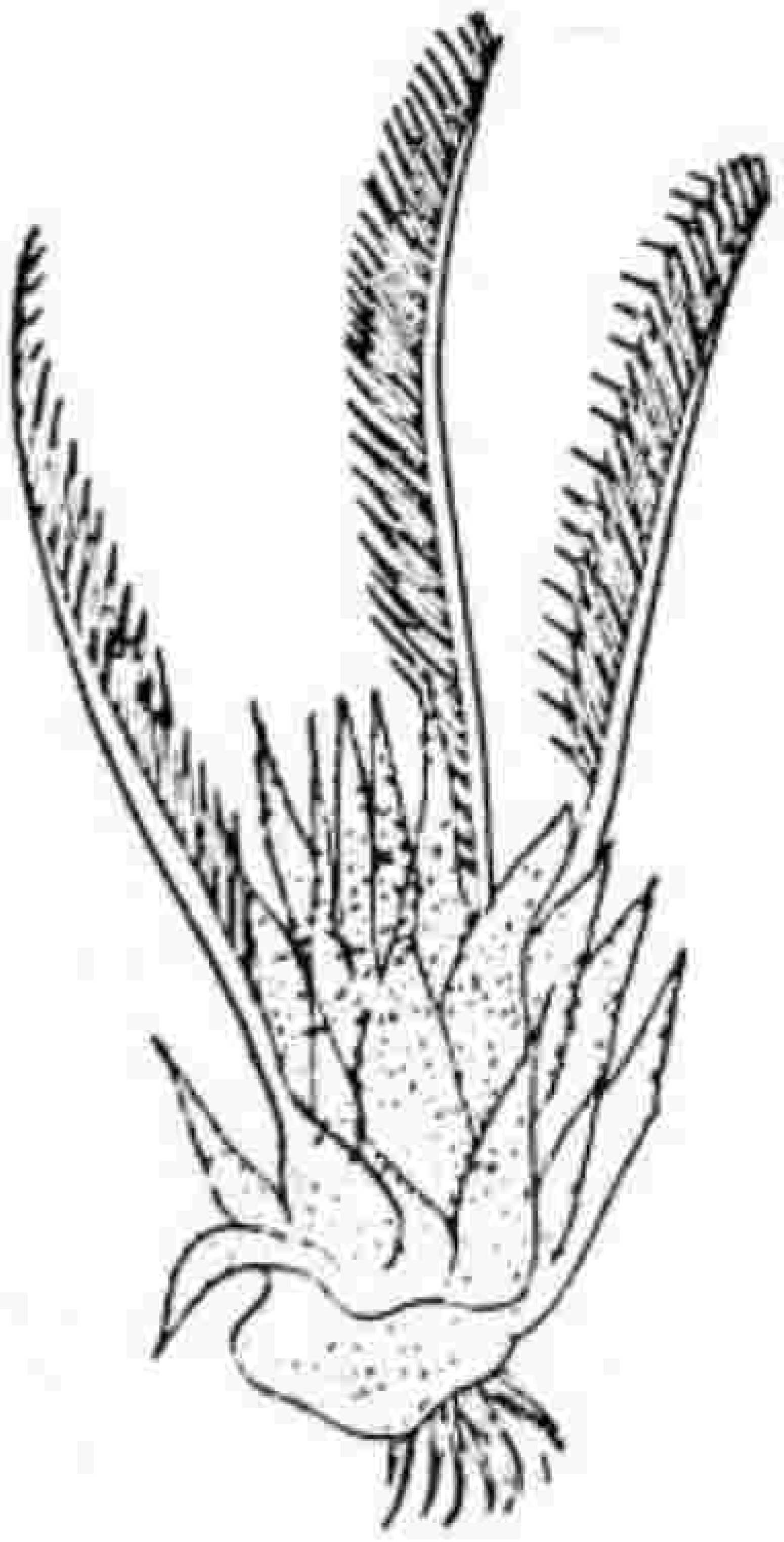


Fig. 8.5: A bulb.

Structure and Development of Microsporangium

Each microsporangium is oval and borne on a short stalk. It consists of several-layered wall enclosing a mass of sporogenous cells. The outermost layer of these cells is tapetum. A large number of microspores are produced in each sporangium.

Each microsporangium develops from a hypodermal cell of microsporophyll. It divides into an outer primary wall cell and an inner archesporial cell. The primary wall cell divides by anticlinal and periclinal divisions form many-layered sporangium wall. The archesporial cell undergoes repeated divisions to give rise to sporogenous cells. The outermost layer of sporogenous cells is called tapetum. The cells of tapetum disintegrate to from tapetal plasmodium which provides nutrition during development of microspores. The sporogenous cells divide and last generation of cells is called microspore mother cells which undergo meiosis to produce tetrads of microspores.

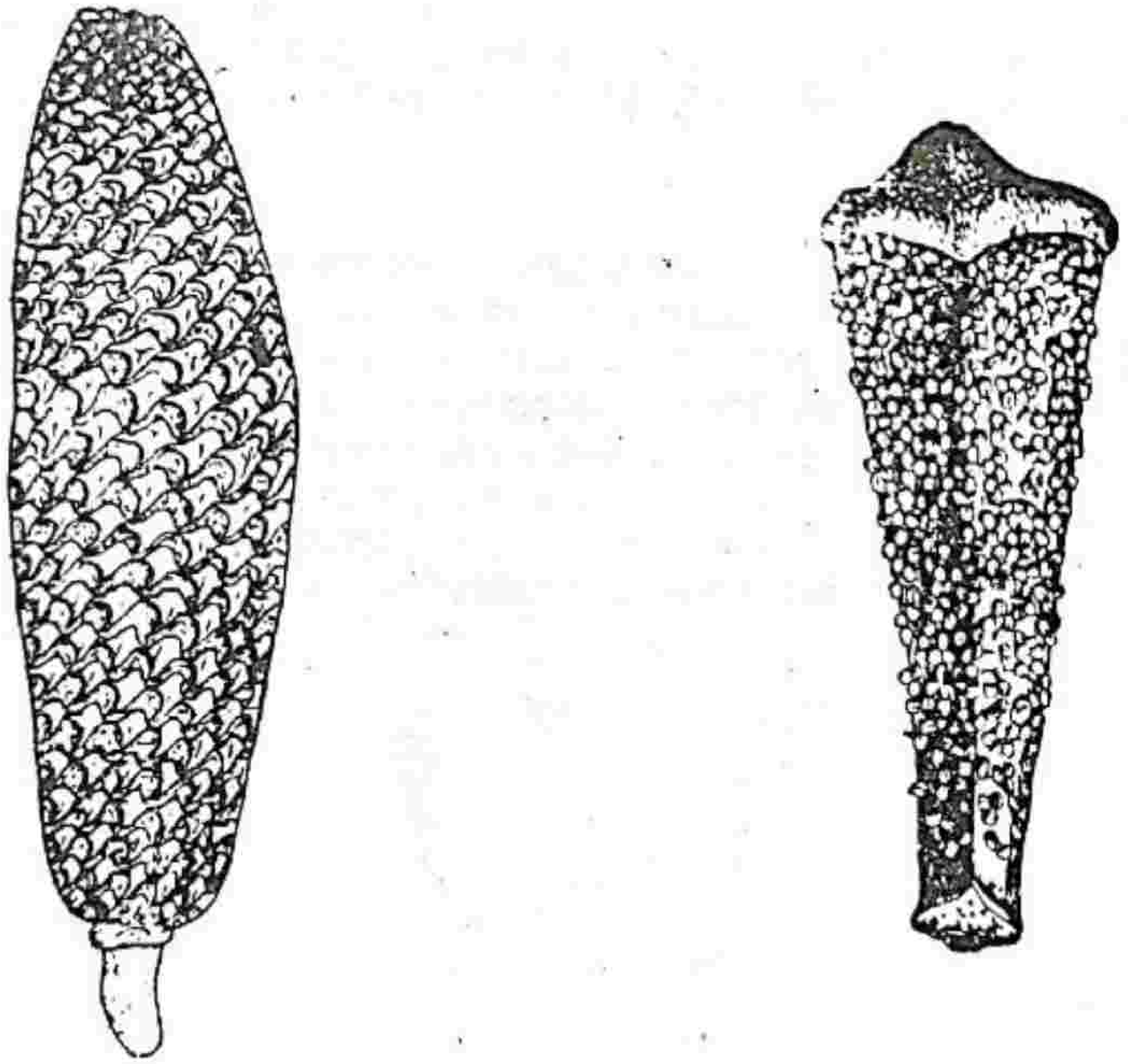


Fig. 8.9: Cycas — A. Male cone, a microsporophyll and microsporangia.

Female Cone

In Cycas, the megasporophylls are not organized into a cone. Therefore, the female cone consists of loosely arranged megasporophylls which surround the shoot apex like the foliage leaves. Each megasporophyll is pinnate leaf-like structure differentiated into an upper, broad, lobed leaf-like portion that tapers to a point; and a lower stalk-like portion known as stipe. The ovules are naked and about 6-8 ovules are arranged laterally on the stipe. The ovules are hairy, red in colour and may reach 6 cm in length.

Structure and Development of Ovule

The ovule is erect and an opening called micropyle is present opposite the point of attachment of the ovule to the megasporophyll. The portion of the ovule farthest from micropyle is called chalaza. The ovule consists of a massive nucellus surrounded by a single integument which is free from upper portion of the nucellus. The integument is histologically differentiated into an outer and inner fleshy layer and a middle layer which becomes stony during seed formation. The nucellus is considered equivalent to megasporangium and consists of thin-walled parenchyma cells having dense cytoplasm. The nucellus grows up into a beak-like outgrowth called nucellar beak. The upper cells of nucellar beak disorganize to form pollen chamber, where the pollens are lodged after pollination.

The ovule develops from a hypodermal cell which divides repeatedly to form a mass of meristematic cells, the nucellus. The integument arise from the base of nucellus and grows at faster rate to surround the nucellus except for its tip.

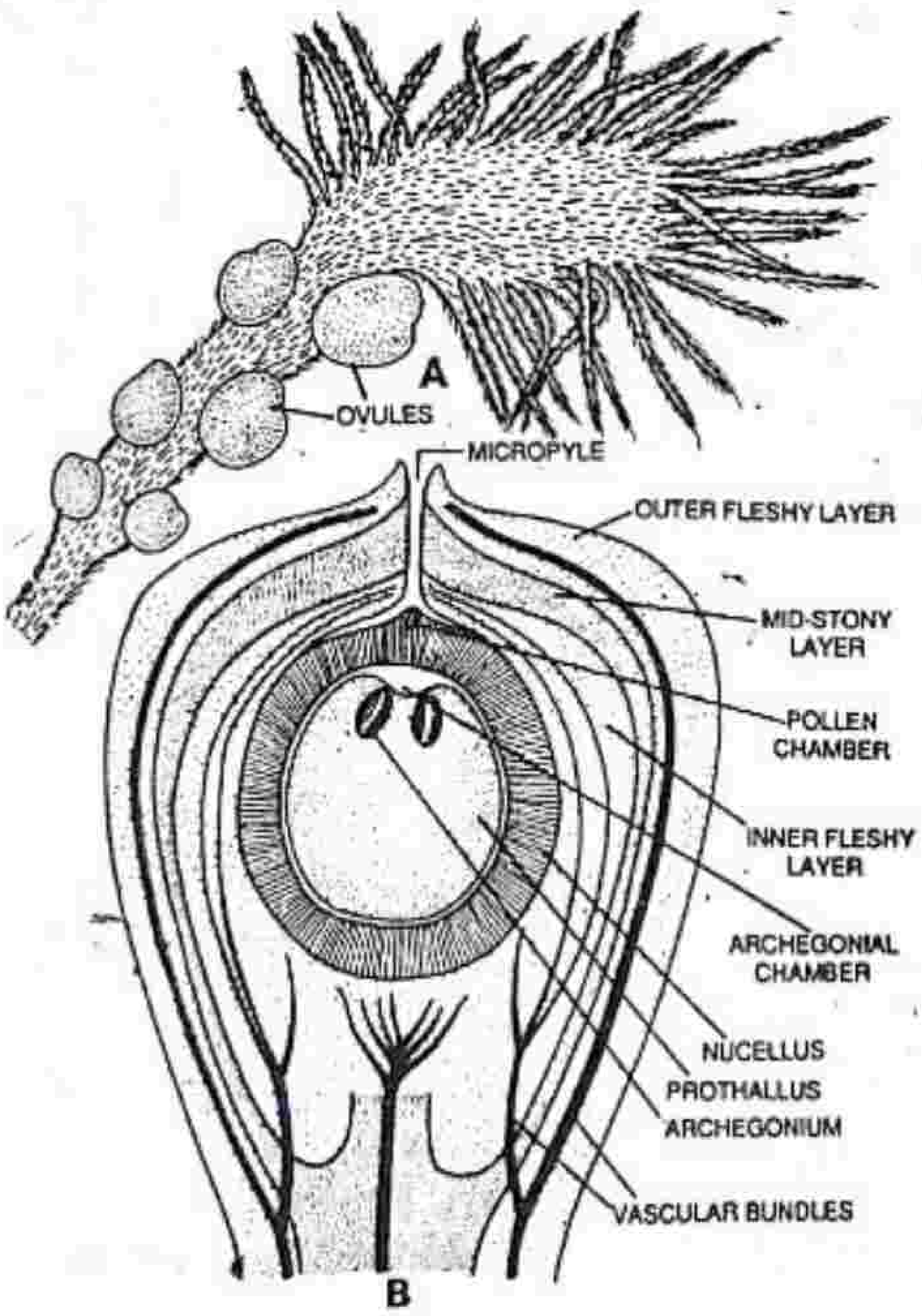


Fig. 8.10: Cycas —Megasporophyll and structure of ovule.

Megasporogenesis

A deeply lying cell of the nucellus enlarge and function as megaspore mother cell. It divides by meiosis to form a linear tetrad of megaspores. The upper three megaspores degenerate and the lowermost enlarge to become embryo sac or female gametophyte.

The Male Gametophyte

The development of male gametophyte starts within the wall of microspore Each microspore is uninucleate and its protoplast is surrounded by two layered wall. The microspore nucleus divides into two and the daughter nuclei are separated by a wall to form a smaller prothalial cell and a larger cell. The larger cell divides and separates a small generative cell and large tube cell. At this stage the microsporphylls are separated by elongation of internodes and the microsporangia are exposed. The sporangium wall ruptures along a vertical line of dehiscence to release 3-celled semi-germinated male gametophytes called pollen grains. These are carried to the female gametophyte by wind where further development of male gametophyte takes place.

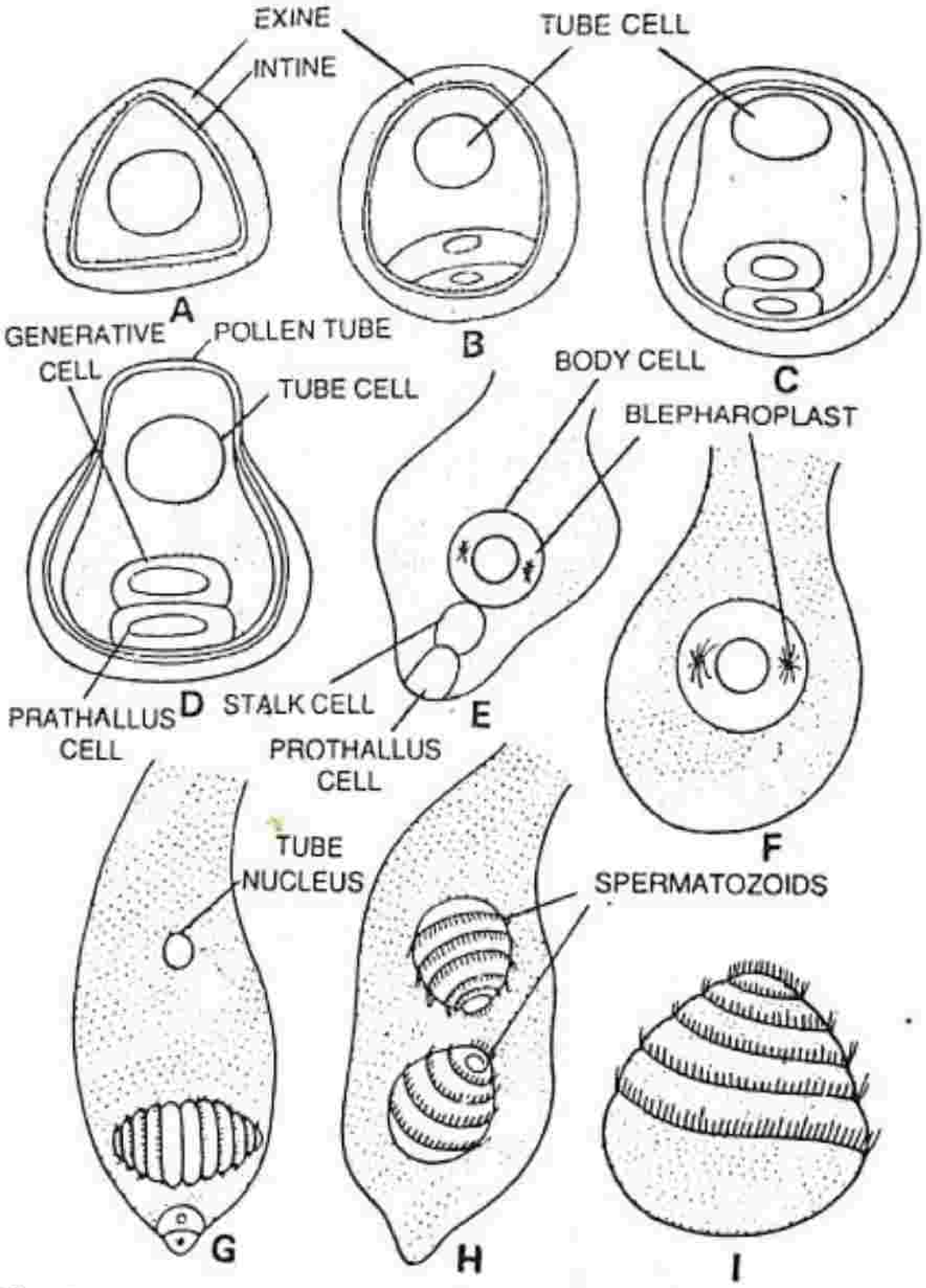


Fig. 8.11: Cycas — Development of male gametophyte.

Pollination

The transfer of pollen grains from microsporangia to the micropyle of the ovule is called pollination. In the meantime some cells at the apex of nucellus disintegrate to produce a colloidal material called pollination droplet. It protrudes out through micropyle and the pollens are caught in it. The droplet dries, contract and carry the pollens into pollen chamber where they remain dormant for 4-6 months.

Development of Pollen Tube

During resting period, the protoplast of each pollen grain protrudes out from the upper end of microspore wall in the form of a tube called pollen tube. The tube nucleus migrates into the pollen tube and the generative cell divides into a stalk cell and a body cell. Just before fertilization, the body cell divides to produce two multiflagellate male sperms or antherozoids. Each sperm consists of a large nucleus surrounded by a thin layer of cytoplasm. The flagella are arranged spirally in the form of a band. The pollen tube is haustorial in nature and it digests its way through nucellus to the archegonia.

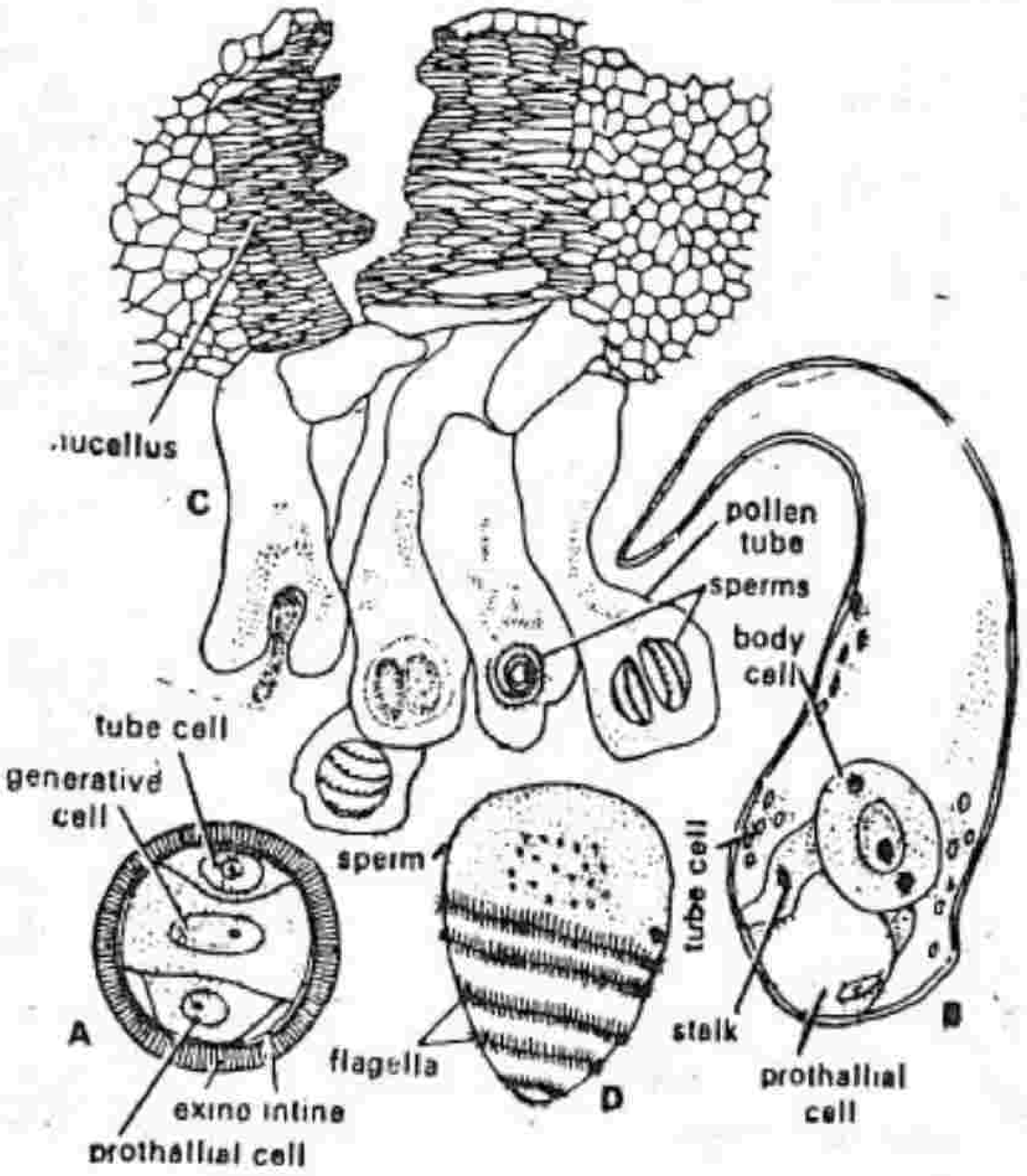


Fig. 8.12: Cycas — Development of pollen tube.

The Female Gametophyte

The functional megaspore in the ovule begins to enlarge and known as embryo sac. The tissue surrounding it becomes vacuolated to form spongy layer that provides nutrition to the developing megaspore. The nucleus of the megaspore divides by free nuclear divisions, i.e., divisions not accompanied with wall formation, to produce 1000 or more daughter nuclei. A vacuole appears in the center during nuclear division. It enlarges and pushes the nuclei to the periphery so that the nuclei become arranged in a peripheral layer. Later additional synthesis of cytoplasm results in gradual disappearance of the vacuole. Now the embryo sac consists of large number of nuclei and water cytoplasm. Cell wall formation starts between peripheral nuclei first and continues in centripetal direction until entire gametophyte becomes cellular. Mature gametophyte is surrounded by two layers, the inner being the megaspore wall.

Structure and Development of Archegonium

A mature archegonium consists of a 4-celled neck and a large egg surrounded by a tough membrane. Few cells of female gametophyte near the micropylar end function as archegonial initials. Each initial divides by periclinal wall to form a smaller outer primary neck cell which divides further to produce four neck cells; and a larger central cell. The nucleus of central cell divides by mitosis to form a small ventral canal nucleus and a large egg. The ventral canal nucleus degenerates soon. The vegetative cells surrounding archegonium form a jacket layer.

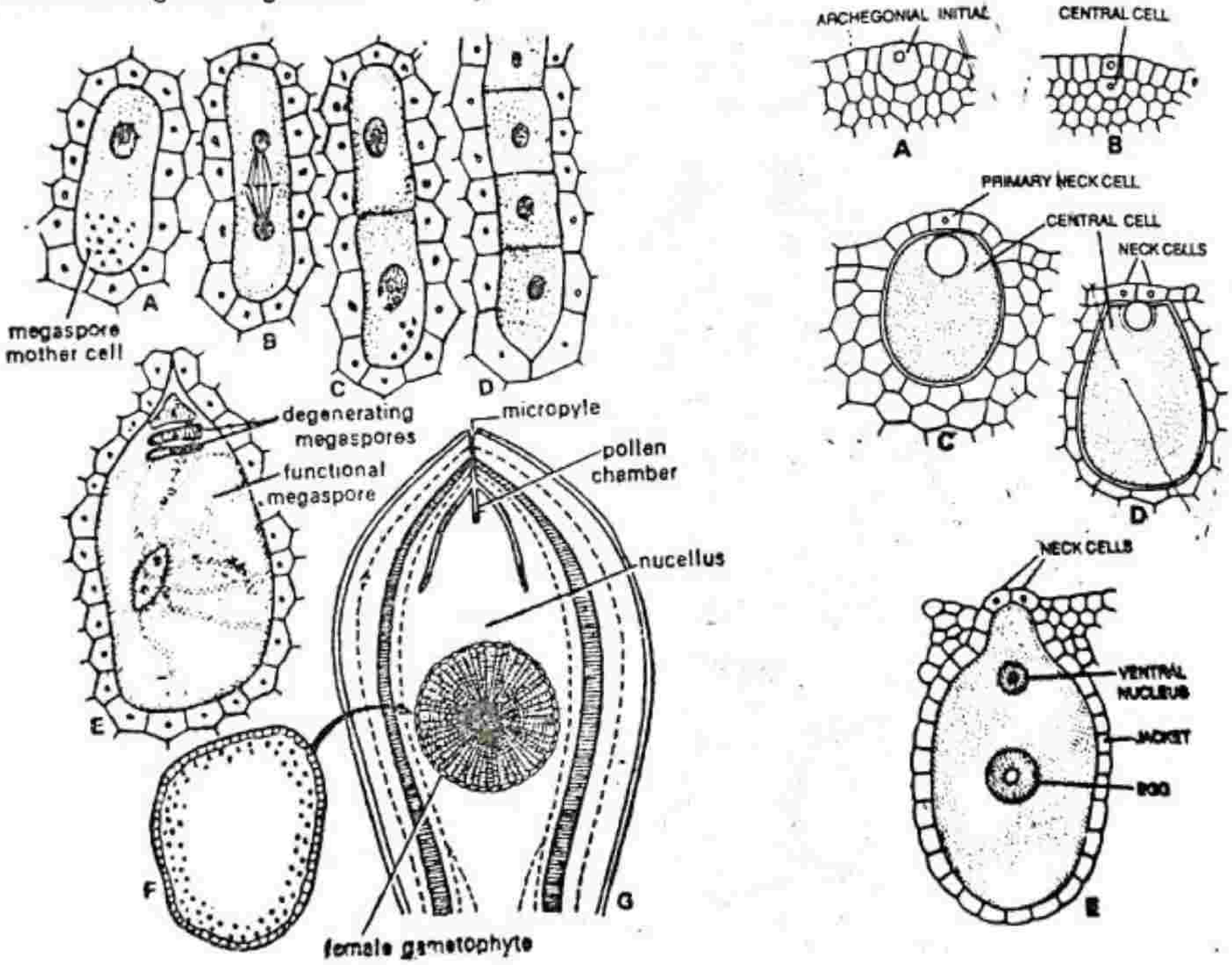


Fig 8.13 Cycas — Development of female gametophyte and archegonium.

Fertilization

As the archegonia mature, the sub-apical cells of female gametophyte increase in size and number to form a depression called archegonial chamber. The archegonia come to lie in this chamber. The tip of the pollen tube bursts to release the male sperms alongwith some fluid. The sperms swim to archegonium neck, lose their flagella, and enter it. The sperm nucleus fuses with egg nucleus to accomplish fertilization and produce diploid zygote.

Development of Embryo

The zygote increases in size and its cytoplasm becomes dense and vacuolated. The nucleus of the zygote migrates to the base and divides by free nuclear divisions to produce 256 or more nuclei. A large central vacuole appears in the center by fusion of many small vacuoles. The nuclei in the basal part of the embryo called proembryo divide rapidly while the nuclei in the rest of embryo cease to divide. The wall formation begins near the base of the archegonium and progresses towards the neck end.

The upper cells of proembryo elongate to form a coiled suspensor whereas the lower cells function as meristematic zone. The cells at the anterior end of meristematic zone organize into cotyledons. A terminal plumule, the shoot end and the foliar appendages, develops between the cotyledons. The cells at the posterior end of the meristematic zone develop into radicle.

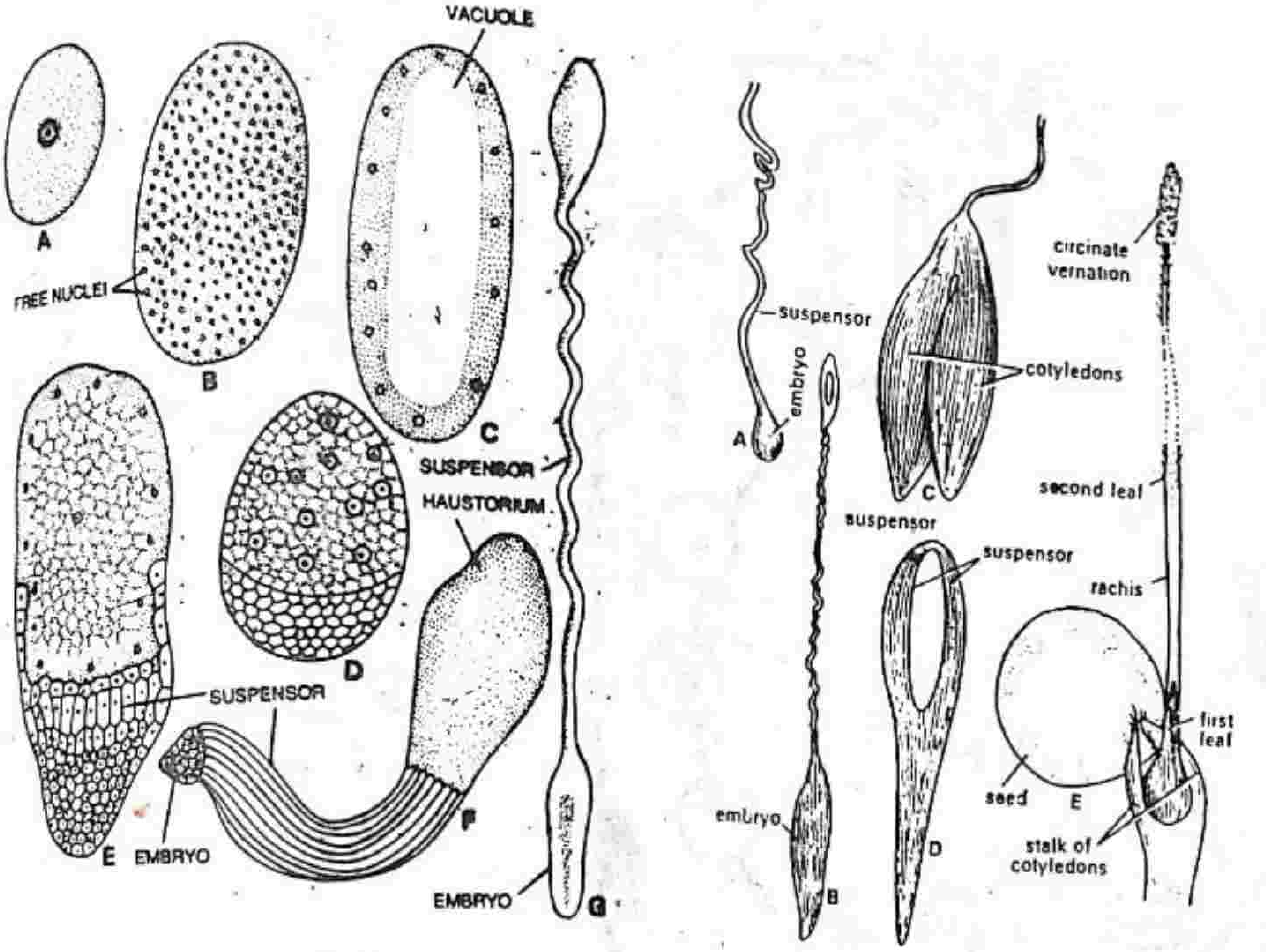


Fig. 8.14: Cycas — Development of embryo.

Seed Formation and Germination of Seed

As the embryo is developing, the ovule increases in size and changes take place in the integument. The outermost layer develops red colour and becomes fleshy; the middle layer becomes stony and hard; and the inner layer remains soft. These layers constitute seed coat are the embryo to form seed.

The seed starts its germination immediately. It absorbs water and the radicle emerges first by rupturing the seed coat at micropylar end. It is followed by plumule. Most part of the cotyledons remain within the seed coat, perhaps absorbing food from the endosperm. Foliage leaves are produced by the activity of apical bud after several years. The seeds remain attached to the young sporophyte by withered cotyledons for one or two years.

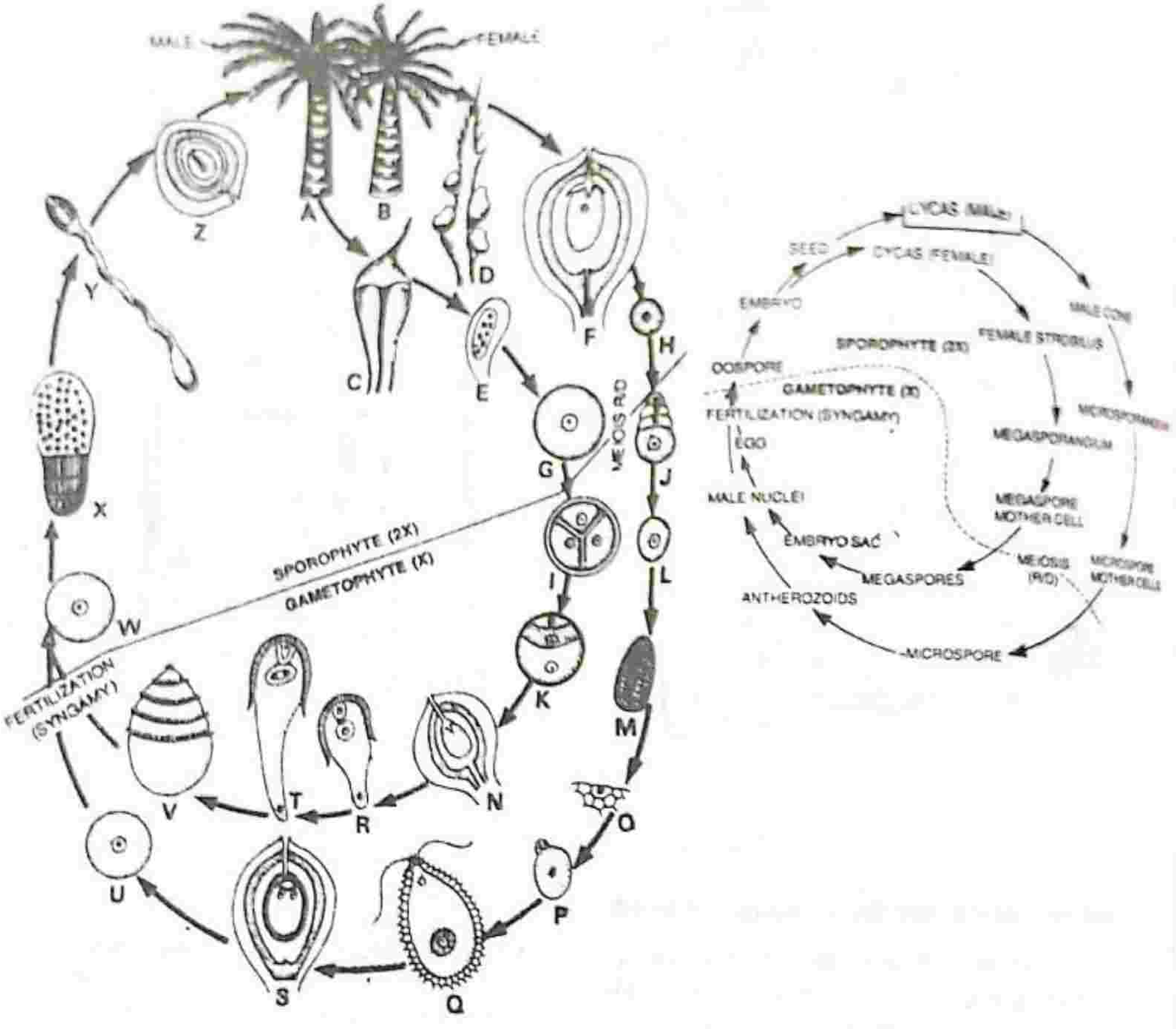


Fig 8.15: Cycas — Life cycle.

CYCAS A LIVING FOSSIL — PHYLOGENY OF CYCADS

The statement that "*Cycas* is a living fossil" refers to phylogeny of the genus, i.e., its evolution and relationship to other gymnosperm groups.

The living *Cycas* retain the following features which presented it as living fossil

1. The *Cycas* belongs to Cycadophyta, a group of comparatively small plants with unbranched stem and pinnate leaves.
2. Their stems contain a large pith, scanty wood and thick cortex.
3. The Cycas like extinct plants retain fern-like leaves that bore seeds on the leaves.
4. The female sporophylls of Cycas which form a loose crown like the male sporophylls of Bennettitales.
5. The seed ferns resemble Cycas in structure of their ovule. The ovules in both possess three-layered integument, two vascular strands traversing the outer and inner fleshy layers, and the nucellar beak with
6. The stem of Cycas and seed ferns is covered with armour of persistent leaf bases. The foliage is fern-like and exhibit circinateptyxis.
7. The wood consists of tracheids and xylem parenchyma cells only. The phloem lacks companion cells and comprises of sieve tubes and parenchyma cells.
8. The megasporophylls in both Cycas and seed ferns are leaf-like.
9. The ovule are large in size and naked.
10. The sporangia group to form sori.
11. The sperms are multiflagellatean motile both in Cycas and primitive plants.
12. The large out put of microsopore from microsporaniga as retain by cycas is also a primitive character.

All these above mentioned common features qualify the Cycas to be referred to as a living fossil.

ECONOMIC IMPORTANCE OF CYCAS

Cycas is important economically as followings:

i. The leaves of *Cycas circinalis* are used to prepare hats, baskets and mats.
ii. The pollens of *Cycas circinalis* are narcotic.
iii. The bark and seeds of *Cycas circinalis* are ground to paste with coconut oil and used for sores and swellings.
iv. The juice of tender leaves of *Cycas circinalis* is useful for flatulence and vomiting.
v. *Cycas revoluta*yields fatty acids and a colouring matter.
vi. The pith and cortical cells of *Cycas revoluta* stem are rich in starch or sago grains.
vii. Several Cycas spp are cultivated for ornamental reasons.
viii. The leaves of Cycas are extensively used in floral decorations.

SOME IMPORTANT QUESTIONS

A. Short Questions

1 What are cycadophytes
2 Give general characters of cycadophytes
3 What is circinatevernation
4 Describe external morphology of Cycas
5 What are coralloid root
6 What is epiblema
7 Which type of vascular bundle is found in cycas
8 Describe secondary growth in cycas
9 Draw strucuture of female cone of cycas
10 What is megasporogensis

B. Long Questions

1 Write general character of cycadophytes
2 Describe economic importance of cycas
3 Describe internal structure of leaf of cycas
4 Write male and female cone of cycas
5 Describe ovule of cycas
6 Describe life history of cycas
7 Is cycas a living fossil?

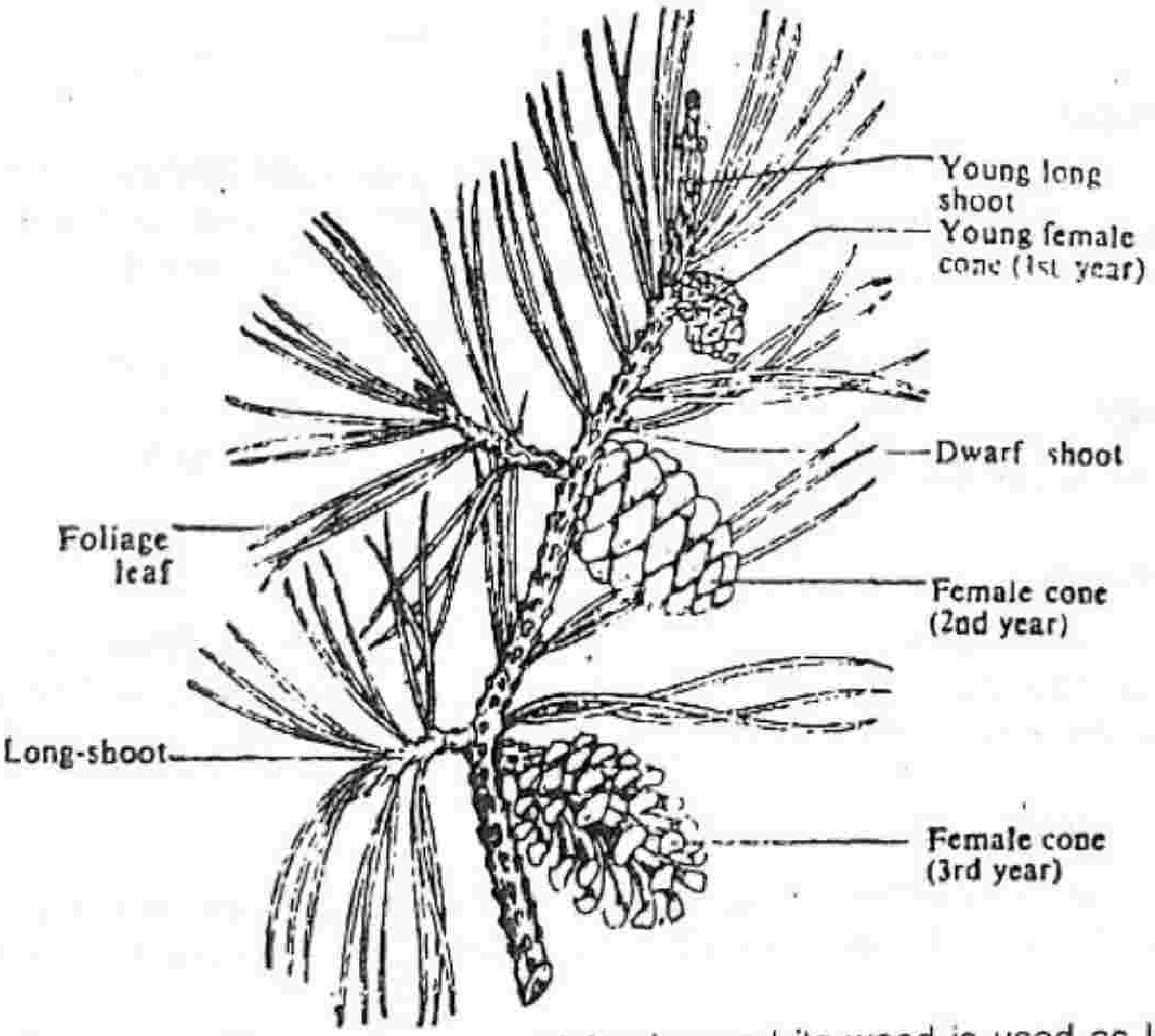
CONIFERALES

Coniferales is the largest and most widely distributed Gymnosperms having about 540 species belonging to 50 different genera. The member of this group form the major part of world forests. The group include some of the largest and the oldest living trees, such as Sequoia, which may attain a height of 300-400 ft with an age of 500-1000 years.

PINUS

Systematic Position

Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	*Pinaceae*
Genus:	*Pinus*



Pinus is a tree with great commercial value and its wood is used as lumber, in the manufacture of paper, for naval stores and other commercial enterprises. The genus consists of about 90 species distributed throughout the world. However, most are found in Northern hemisphere. The common species of sub-continent are: *Pinuswallichiana*(blue pine), *Pinusroxburghii* (chir pine), *Pinusgerardiana*(chilgoza pine) and *Pinusinsularis* found growing on slopes at altitudes between 1800-7000 meters.

Vegetative Morphology

The Pinus plant is an evergreen sporophyte. It varies in height from 70-200 feet. The plant body can be differentiated into root, stem and leaves.

The Root

The root is tap root that branch extensively to form a massive root system. Some branch roots divide repeatedly to form a cluster of rootlets. These get infected with fungus and are called mycorrhizal roots. These help in absorption of water.

The Stem

The main stem is cylindrical and branched. The branches are horizontal and confined to the upper part of the stem. The lower branches are larger and upper smaller. This arrangement provides plant a pyramid-like look. In most species a whorl of branches is produced each year. Two kinds of branches are found in Pinus:

i.Long Shoots

These are normal branches which continue to grow actively for indefinite period, therefore also called branches of unlimited growth. These branches arise at regular intervals on the main trunk, are horizontal, taper towards apex and covered with scale leaves.

ii.Dwarf Shoot

These arise on the long shoots in the axils of scale leaves. These grow for a limited period therefore called branches of limited growth. Like long shoots these are covered with scales leaves called cataphylls. In addition they bear pine needles at their tips.

The Leaves

The leaves are of two types:

i.Scale Leaves

These are brown in colour and protective in nature. These develop on long shoots and at the base of dwarf shoots. The scale leaves on the dwarf shoots are called cataphylls which possess a distinct midrib.

ii.Needle Leaves

These are needlelike and develop singly or in groups at the apices of dwarf shoots called spurs. The spurs grow in the axils of scales leaves on long shoots.

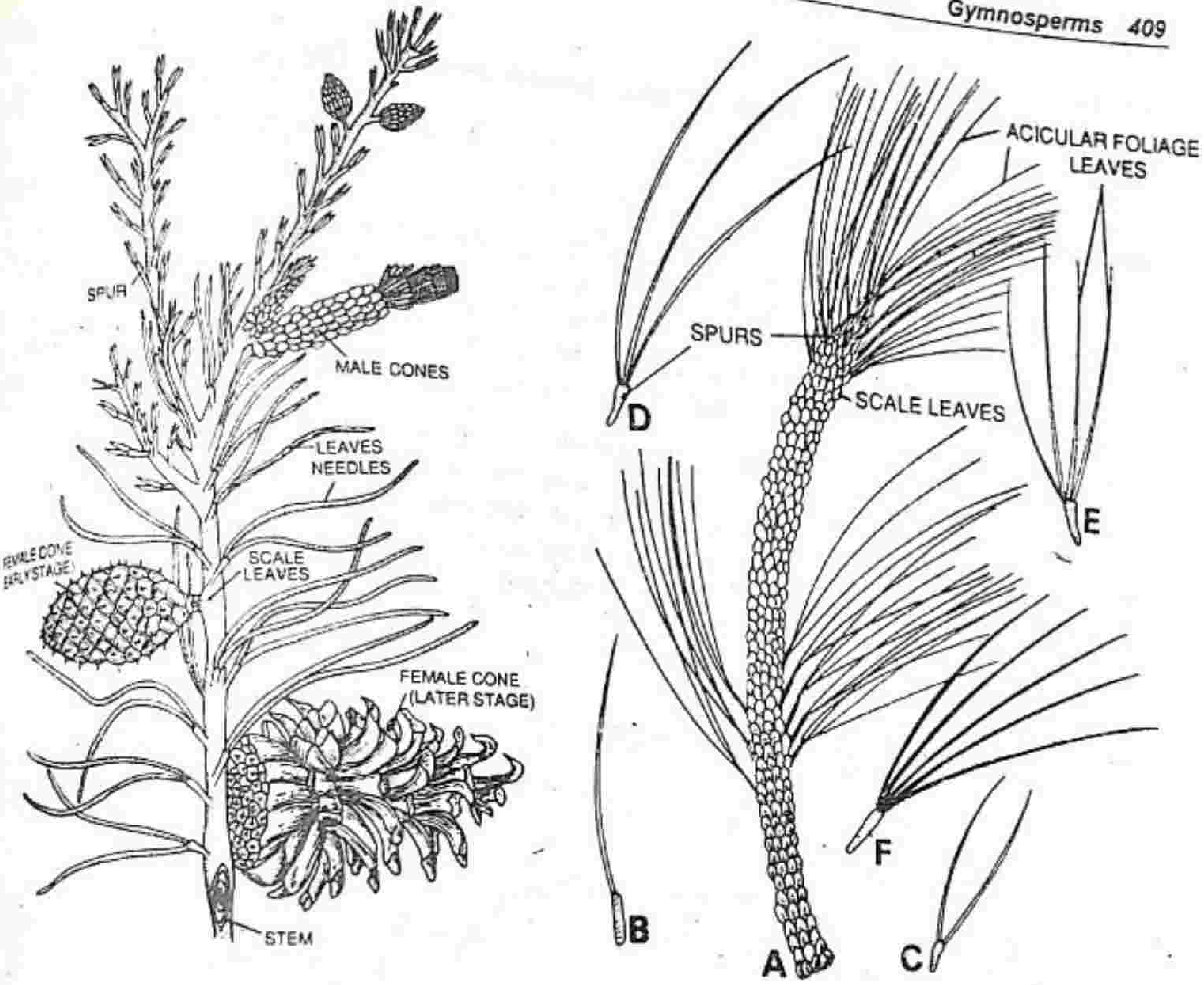


Fig. 8.16: Pinus— Vegetative morphology and details of long and dwarf shoots.

INTERNAL ANATOMY

The Root

Piliferous Layer

The outermost layer in root is single-layered piliferous layer. It is protective in nature.

Cortex

Beneath the epidermis there is a wide zone of parenchymatous cells forming the cortex.

Endodermis

The innermost layer of cortex is called endodermis. It is single layer of cells. In mycorrhizal root fungal hyphae are present among the cortical cells. These occupy intercellular spaces usually.

Pericycle

Next to endodermis there is many-layered pericycle. The pericylce cells contain starch.

Vascular Tisues

The vascular tissue consists of xylem occupying the center of the axis in older roots, however in young roots the center is occupied by pith. The number of xylem bundles range from 2-4, but it is diarch usually. The protoxylem is forked so that the xylem bundles appear to be Y-shaped. The phloem bundles alternate with xylem bundles. The number of phloem bundles is equivalent to xylem bundles.

Secondary growth in root is by development of cambial strips in parenchyma present between phloem and metaxylem and by pericycle cells present above the protoxylem. Secondary xylem is produced towards the centre and secondary phloem towards the outer side. The epidermis is replaced by periderm that develops from phellogen or cork cambium which arises in pericycle.

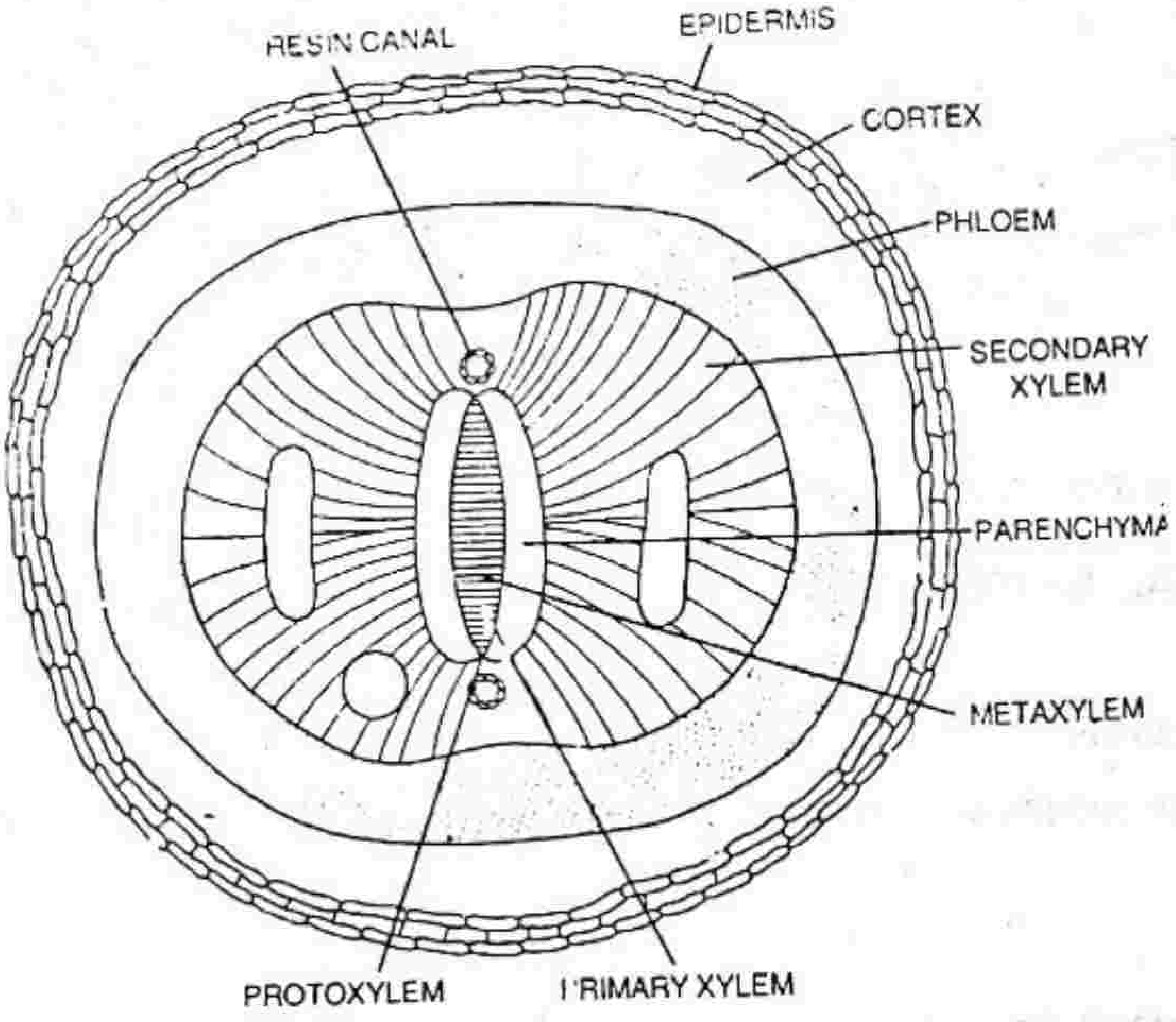


Fig. 8.17: Pinus— Internal structure of root.

THE STEM

Epidermis

The outermost tissue in stem is epidermis. It is single layered and the outer wall of epidermal cells are covered with a massive cuticle.

Cortex

Beneath the epidermis a massive cortex composed of parenchyma cells is present. The coritcal cells beneath the hypodermis are thin-walled and contain chloroplasts and resin canals. The cortical cells are sclerified and form hypodermis. The endodermis and pericycle are not conspicuous.

Vascular Tissues

The vascular bundles are conjoint collateral, open and arranged in a ring. The xylem consists of tracheids, xylem parenchyma and is traversed by uniseriate xylem rays. The phloem comprises of sieve tubes and phloem parenchyma cells. The xylem and phloem of each vascular bundle is separated by a single layered vascular cambium. The vascular bundles are separated by parenchymatous medullary rays. The center of the young stem is occupied by pith consisting of parenchyma cells.

Secondary growth

The secondary growth results in the formation secondary vascular tissue. Secondary xylem develops on inner side of vascular bundle and consists of tracheids and parenchyma cells arranged radially to form xylem rays. More secondary xylem is produced than secondary phloem. The secondary phloem is produced towards the outer side of the vascular bundles and comprises of sieve tubes, phloem parenchyma cells. Fibres and sclereids are also found in secondary phloem. Due to excessive development of secondary xylem, the sieve elements of primary and secondary phloem are crushed except for those formed most recently by vascular cambium. The epidermis is replaced with periderm that develops from phellogen which arises in the outermost layers of cortex.

The vascular cambium shows seasonal acitivity, therefore annual rings consisting of winter and spring wood are prominent. The spring wood is more massive than the winter wood as vascular cambium ceases its activity and remains dormant during autumn and winter. Each annual ring represents growth of one year usually.

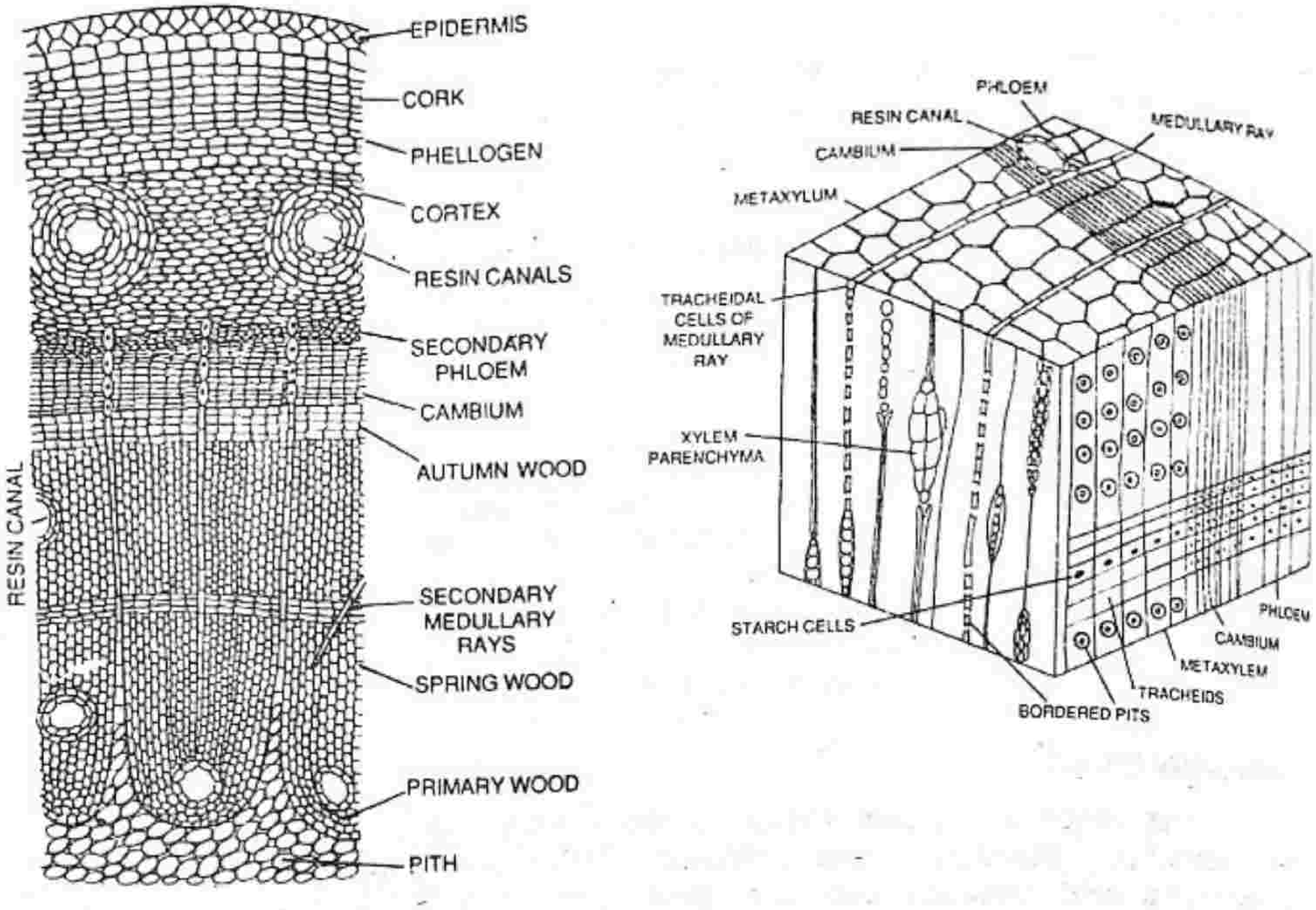


Fig. 8.18: Pinus—A.Internal structure of stem; B. Three dimensional diagram of secondary wood.

THE LEAF

The pine needles exhibit xerophytic characteristics. The leaf of *Pinusmonophylla*is circular in outline whereas those of *Pinusroxhurghii* and *Pinuswallichiana* are triangular.

Epidermis

The outermost layer is epidermis. The epidermal cells are extremely thick-walled and heavily cutinized. The stomata are sunken, i.e., present in depressions below the level of epidermis, and occur on all surfaces of the needle (amphistomata).

Hypodermis

Beneath the epidermis a single or many-layered hypodermis is present. It is composed of thick-walled sclerenchyma cells. The hypodermis is more massive at corners and is interrupted by air spaces beneath the stomata.

Mesophyll Cells

The mesophyll (ground tissue) is compact and comprises of parenchymatous cells. Each mesophyll cell is trabeculate, i.e., finger-like projections arise from their walls which move inwardly into the cell cavity. Numerous chloroplasts are arranged on these projections. Resin canals are present in the mesophyll.

Endodermis

A conspicuous single-layered endodermis delimits the central tissue from mesophyll. The endodermal cells are large, oval and Casparian strips are present in them.

Vascular Bundle

The central part of the leaf is occupied by one or two vascular groups embedded in the transfusion tissue. Trasfusion tissue consists of several layers of compactly arranged cells. It consists of transfusion tracheids which have thick lignified walls with bordered pits and transfusion parenchyma cells which contain chloroplasts. The cells of the transfusion tissue are in direct contact with endodermal cells, thus considered to be concerned with conduction of materials between the vascular bundles and mesophyll. The vascular bundles are separated by a band of sclerenchymatous fibers. Each vascular bundle consists of phloem facing the curved outer side and xylem that faces the pointed end of needle. The xylem is reduced and simple and most conduction is done by transfusion tissue.

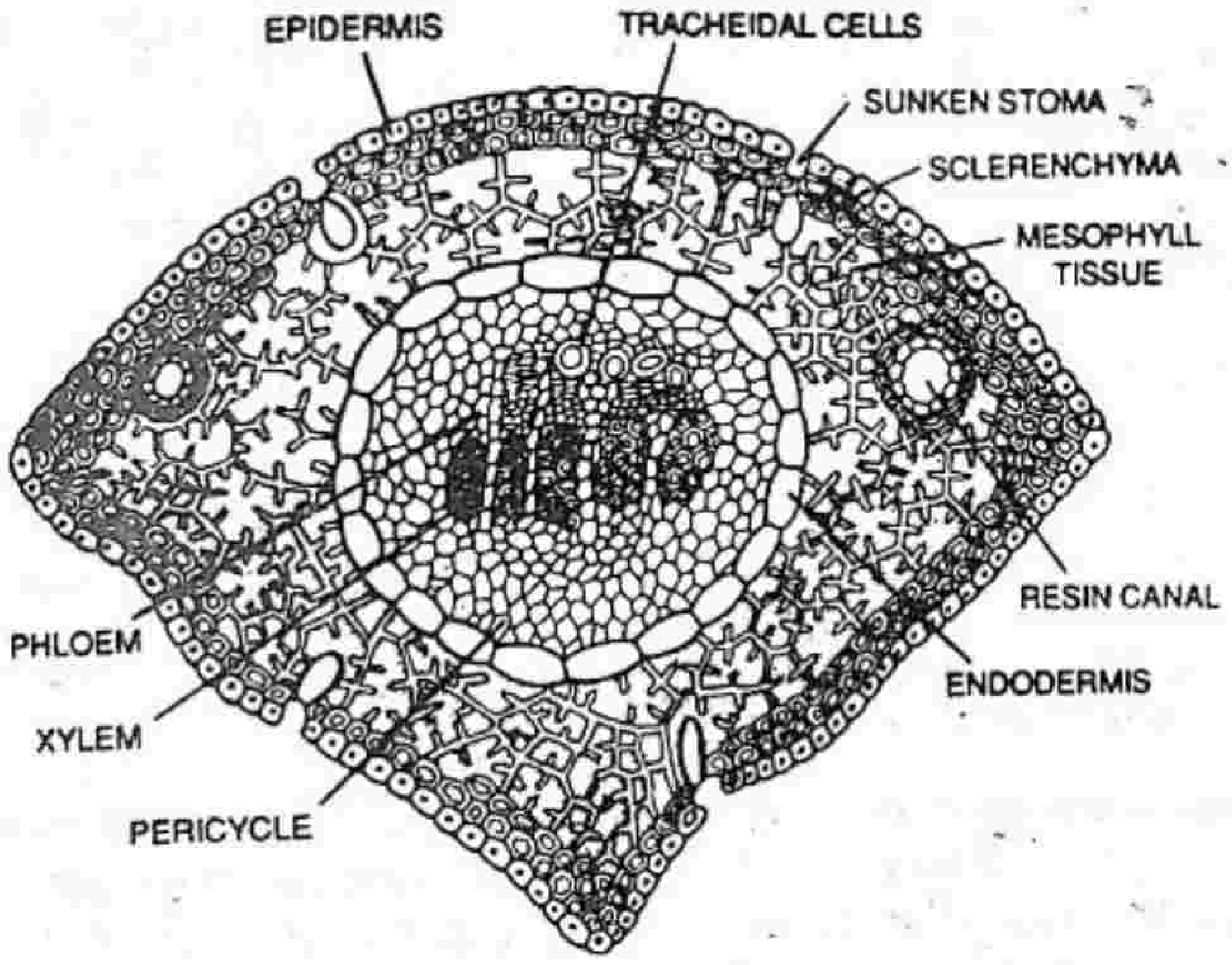


Fig. 8.19: Pinus— Internal structure of pine needle.

Reproduction

Pinus is heterosporous and the spore producing structures are microsporangia and megasporangia that develop on microsporophylls and megasporophylls respectively. The sporophylls are arranged into separate cones borne on the different branches of the same plant. The male cones develop in clusters around the base of terminal bud of a branch. The female cone develop on a dwarf shoot near its apex. The female cone of Pinus is the largest among the gymnosperms.

The Male Cone

Each male cone consists of an axis upon which microsporophylls are arranged spirally. Each microsporophyll is a flattened appendage that end in expanded head. The head is turned up and fit over the microsporophyll above it. Two microsporangia develop on the lower surface of each microsporophyll.

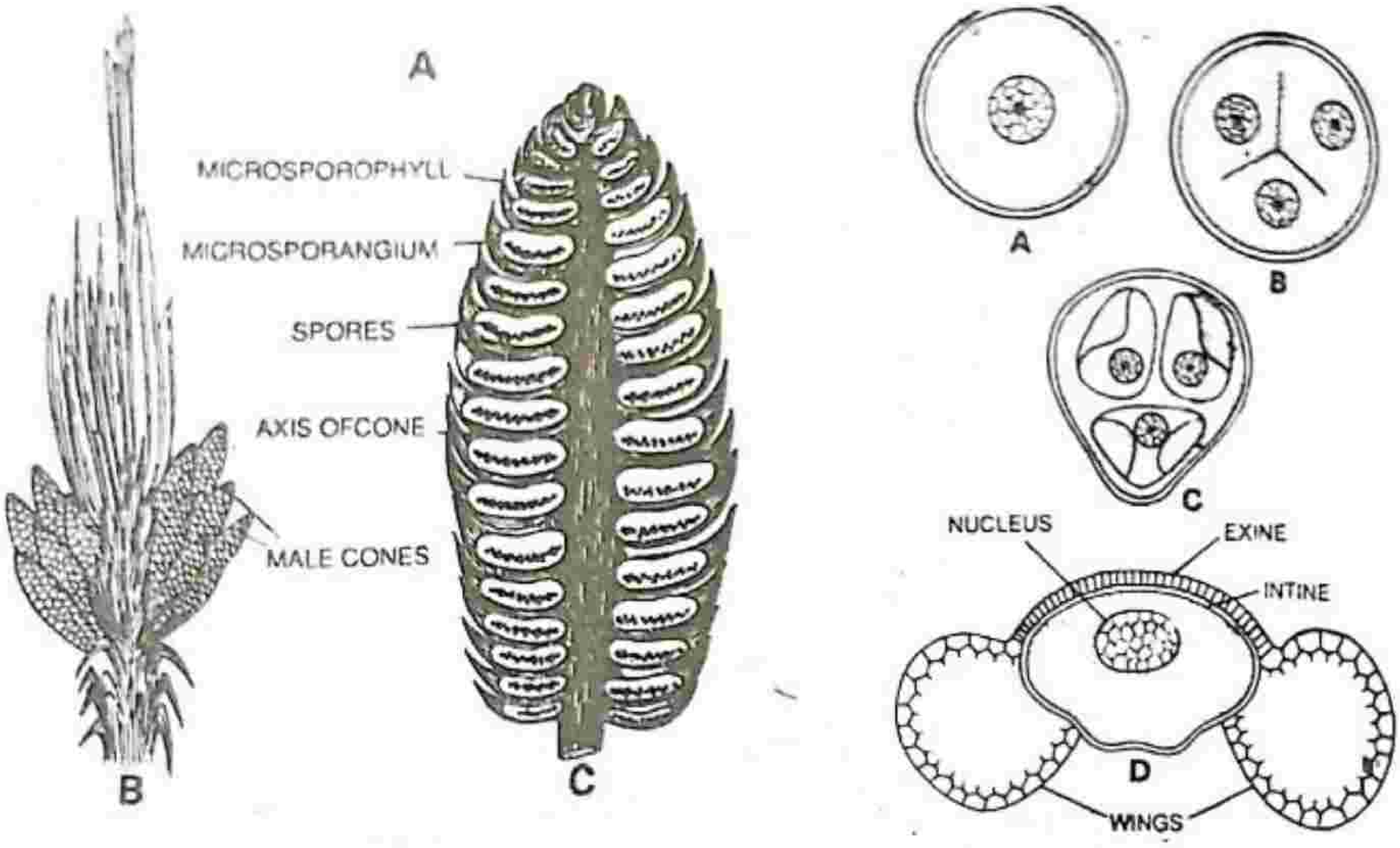


Fig. 8.20: Pinus— Male cone and development of microspores.

Structure and Development of Microsporangium

A mature microsporangium consist of four layered sporangium wall surrounding a mass of microspore mother cells. The cells of outermost wall layer consists of cells with reticulate, helical or annular thickening. These cells help in dehiscence. The innermost wall layer act as nutritive layer, the tapetum.

Each microsporangium originates from a layer of hypodermal cells. These cells divide periclinally to produce and outer layer of cells called parietal layer and inner layer of cells known as archesporial cells. The cells of parietal layer divide by anticlinal and periclinal division to form a 4-layered sporangium wall. The cells of innermost wall layer act as tapetum. The archesporial cells differentiate into spore mother cells which undergoes meiosis to produce tetrads of microspores. The spores separate and develop air bladders or wings.

The Female Cone

Each female cone consists of an axis upon which a series of appendages called bract scales is arranged. A thick wedge-shaped woody scale called ovuliferous scale arises in the axil of each bract scale. It is attached to the bract scale. Its broader end is sterile, rhomboidal in outline and directed outwards to conceal the bract scale. Two ovules are borne on the upper surface near the base of the of ovuliferous scale.

The Ovule

Each ovule is in the form of a small white rounded swelling. It consists of a massive integument surrounding a small nucellus. The integument is attached to the lower portion of the nucellus only. A narrow passage, the micropyle is present near the top of the ovule.

A deeply lying cell is differentiated from adjacent cells by its larger size and prominent nucleus. It is called megaspore mother cell. The surrounding tissue develops into nutritive spongy tissue. The megaspore mother cell undergoes meiosis to produce a linear tetrad of megaspores. The upper three megaspores degenerate and the surviving megaspore enlarges and acts as functional megaspore.

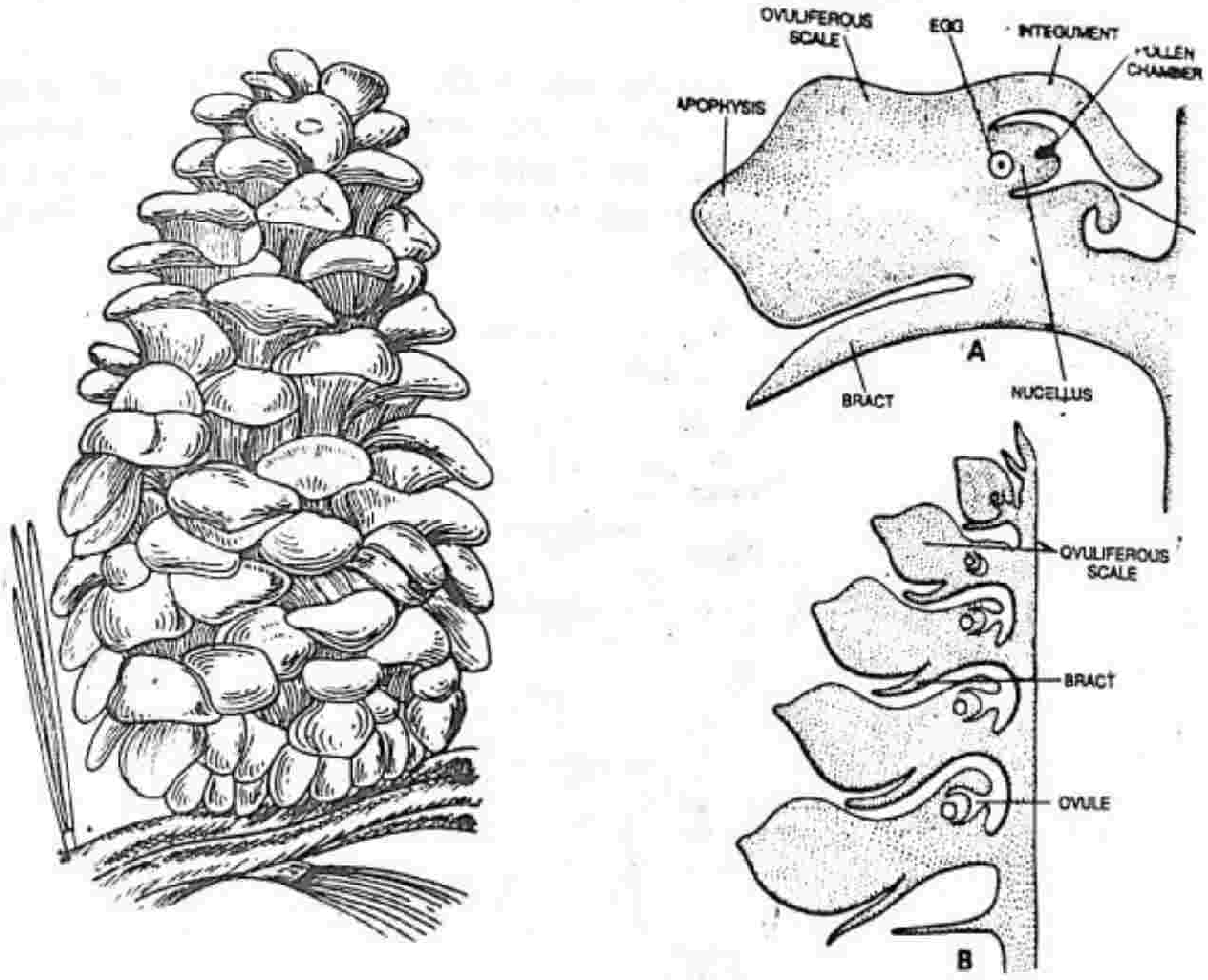


Fig. 8.21: Pinus— Female cone an structure of ovuliferous scale.

THE GAMETOPHYTES

The spores start germinating into gametophytes with their respective sporangia. Therefore, the development of gametophytes is endosporic.

Male Gametophyte

Each microspore is unicellular and surrounded by two-layered wall, the inner intine and outer exine. At lower end of the exine a thin area is present through which the pollen tube emerges. The nucleus of microspore undergoes three successive division to produce two prothalial cells, a generative cell and a tube cell. This 4-celled semi-germinated male gametophyte called pollen grain. It is shed from the microsporangium and is taken to pollen chamber in the female gametophyte where further development takes place.

After pollination, the generative cells degenerate and the intine grows out in the form of pollen tube. The pollen tube is branched and haustorial in nature. The generative cell divides to form a stalk cell and a body cell. These cells move into the pollen tube. The nucleus of the body cell divides to form two sperm nuclei of unequal size. The tube nucleus lies near the tip of the pollen tube.

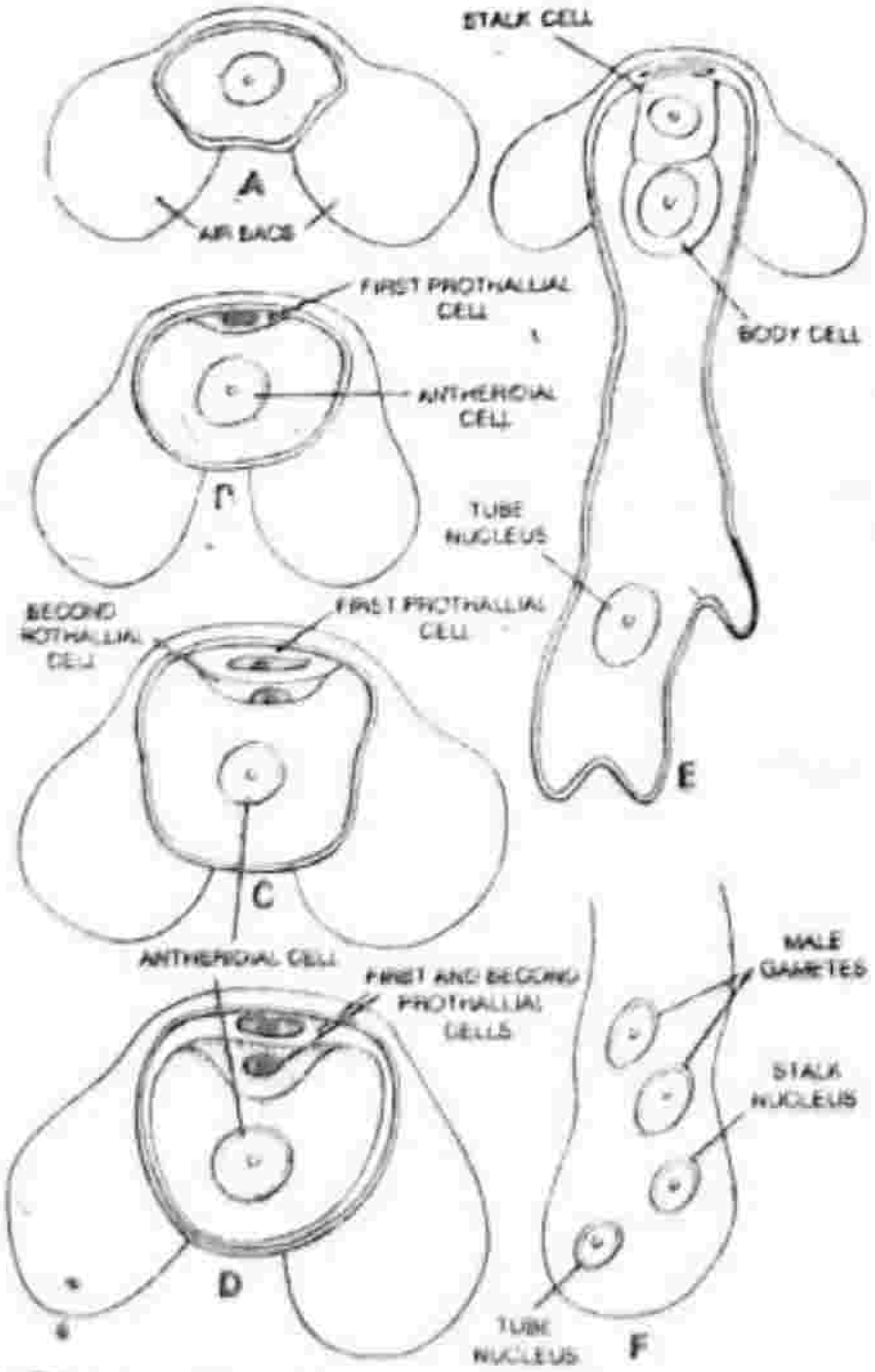


Fig. 8.22 Pinus— Development of male gametophyte.

Female Gametophyte

The functional megaspore enlarges in size and its nucleus divides by free nuclear division to form about 2000 nuclei. A large vacuole appears in the center and all nuclei come to lie nearer periphery. Additional cytoplasm is synthesized and the central vacuole is replaced with water cytoplasm. The wall formation starts from periphery and gradually proceeds towards the center. The megaspore wall surrounding the gametophyte become thick. The ovule also increase in size at the same time.

Structure and Development of Archegonium

Each archegonium consists of a short neck and large venter. The surrounding vegetative cells of female gametophyte form jacket layer around the archegonium. The number of archegonia differ from species to species from one to six.

Several gametophyte cells at micropylar end function as archegonial initials. Each archegonial initial divides by a periclinal division into an outer primary neck cell and an inner central cell. The primary neck cell divides by two successive anticlinal divisions to form a plate of four neck cells. These cell divide periclinally to form 8-celled neck, the cells being arranged in two tiers. The neck canal cells are absent. The nucleus of the central cell enlarges and migrate near the neck region. It divides unequally to form a small ventral canal cell and a large egg cell. The ventral canal cell disintegrate and the egg nucleus migrates to the center.

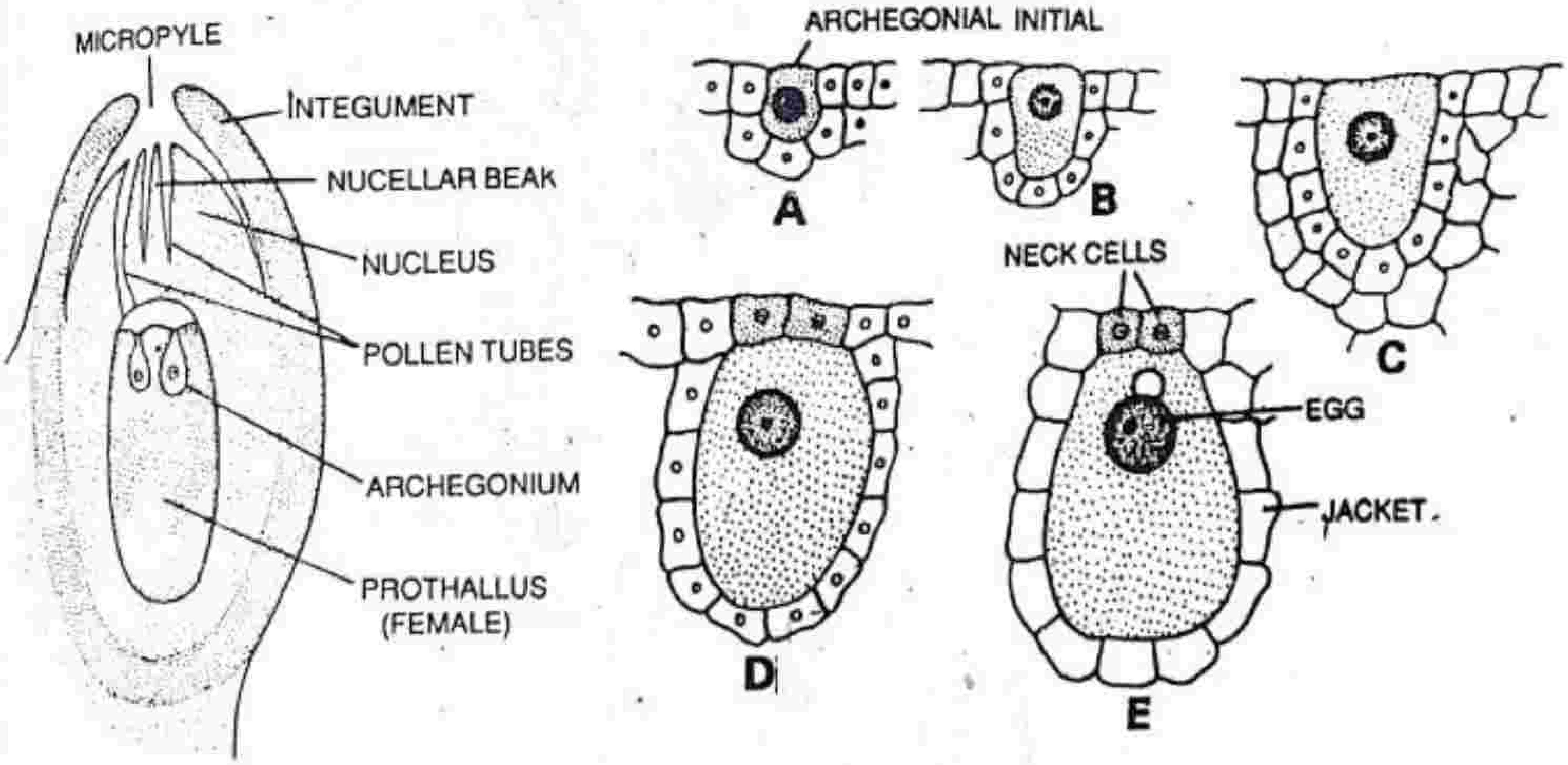


Fig. 8.23: Pinus— A mature ovule and development of archegonium.

Pollination

The pollen grains are carried to female cone by wind. The ovuliferous scales become separated and the pollen grains sift down between the scales and then lodged in the micropylar canal of the ovule. They are caught in the pollination drop that develops at the mouth of micropyle. The drop dries and the pollens are drawn into the pollen chamber where the development of the male gametophyte is completed.

Fertilization

After formation of sperm cells, the pollen tube grows actively through nucellus and the tip of the pollen tube forces itself through neck cells of archegonium. It ruptures and release the sperm cells. The larger sperm unites with egg to form diploid zygote.

Embryo Development

The zygote nucleus divides twice to form four nuclei. These nuclei move towards lower end of egg cell and divide to form eight nuclei which arrange themselves into two tiers of four nuclei each. Vertical walls separate the nuclei of each tier. Then the cross walls separate the four basal cells to form lower tier. The cells of upper and lower tier divide again to form four tiers of four cells each. The lowermost tier is embryo tier, next to it are suspensor tier, rosette tier and open tier. This 16-celled embryo is called proembryo.

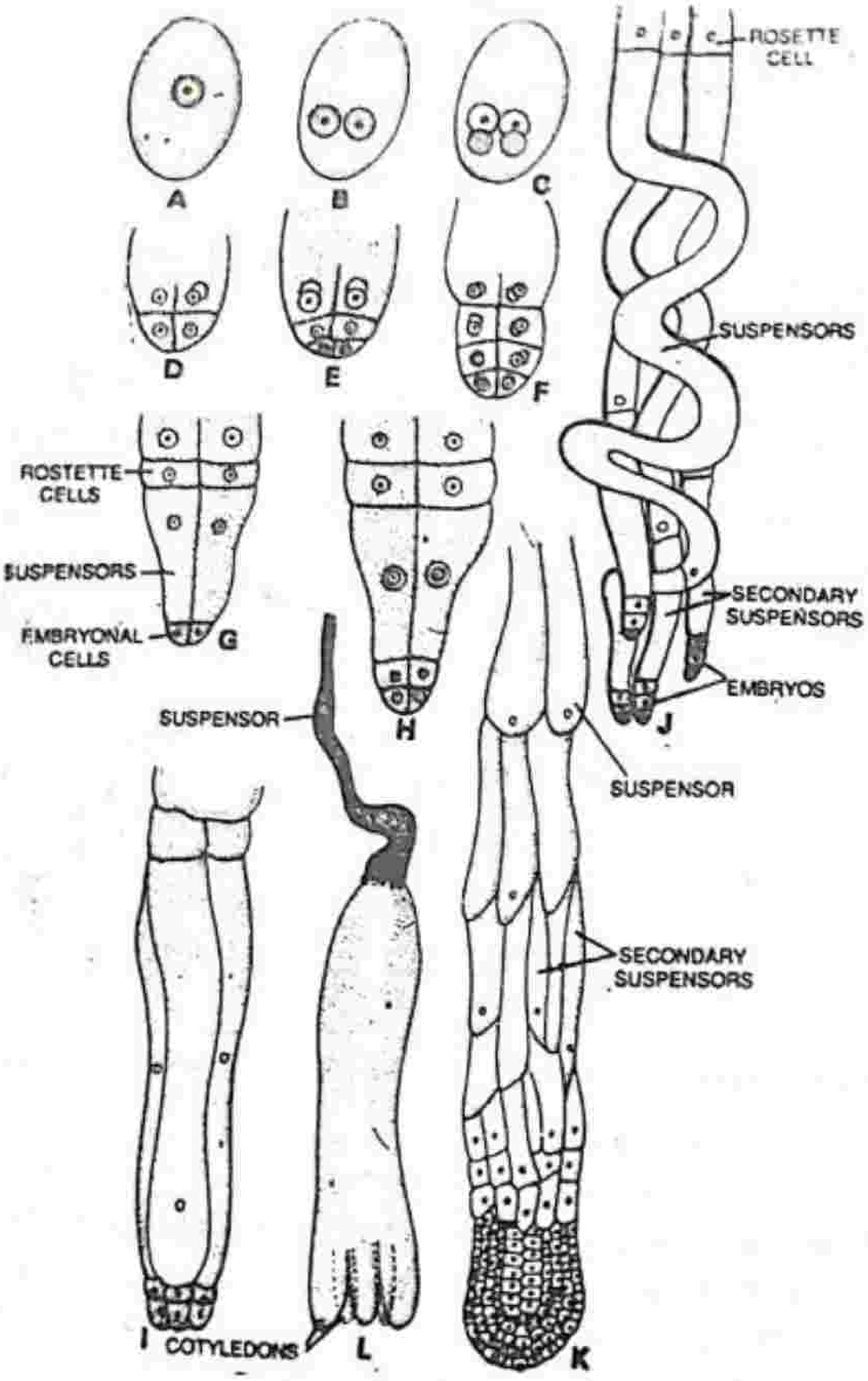


Fig. 8.24: Pinus— Development of embryo.

Cleavage Polyembryony

Pinus exhibits cleavage polyembryony, i.e., cells of proembryo develop independent of each other to 4-8 separate embryos. The suspensor cells elongate to form primary suspensors which push the cell of the embryo tier into the vegetative tissue of gametophyte. The primary suspensors become coiled and buckled. Some of the embryonal cells divide and elongate to form embryonal tubes which function as secondary suspensors and push the embryo system further into the cavity. The lower end of the embryo system separates or cleaves into four distinct vertical series of cells. Each series consists of an apical cell, two or more embryonal tubes, and a primary suspensor cell. One of the developing embryo outcompete the others and occupies a major portion of the female gametophyte. The other developing embryos abort.

Development of Seed

A mature embryo consists of a whorl of cotyledons (usually eight in number) which surrounds a shoot apex, a short hypocotyl and a radicle. During embryo development the integument layers undergo changes. The inner fleshy layer degenerates and becomes papery to form tegmen (inner seed coat) or testa. Most of the nucellar tissue is used by developing embryo and the remaining organizes itself at the micropylar end to form perisperm. The nutrition rich cells female gametophyte surrounding the embryo form the endosperm of the seed.

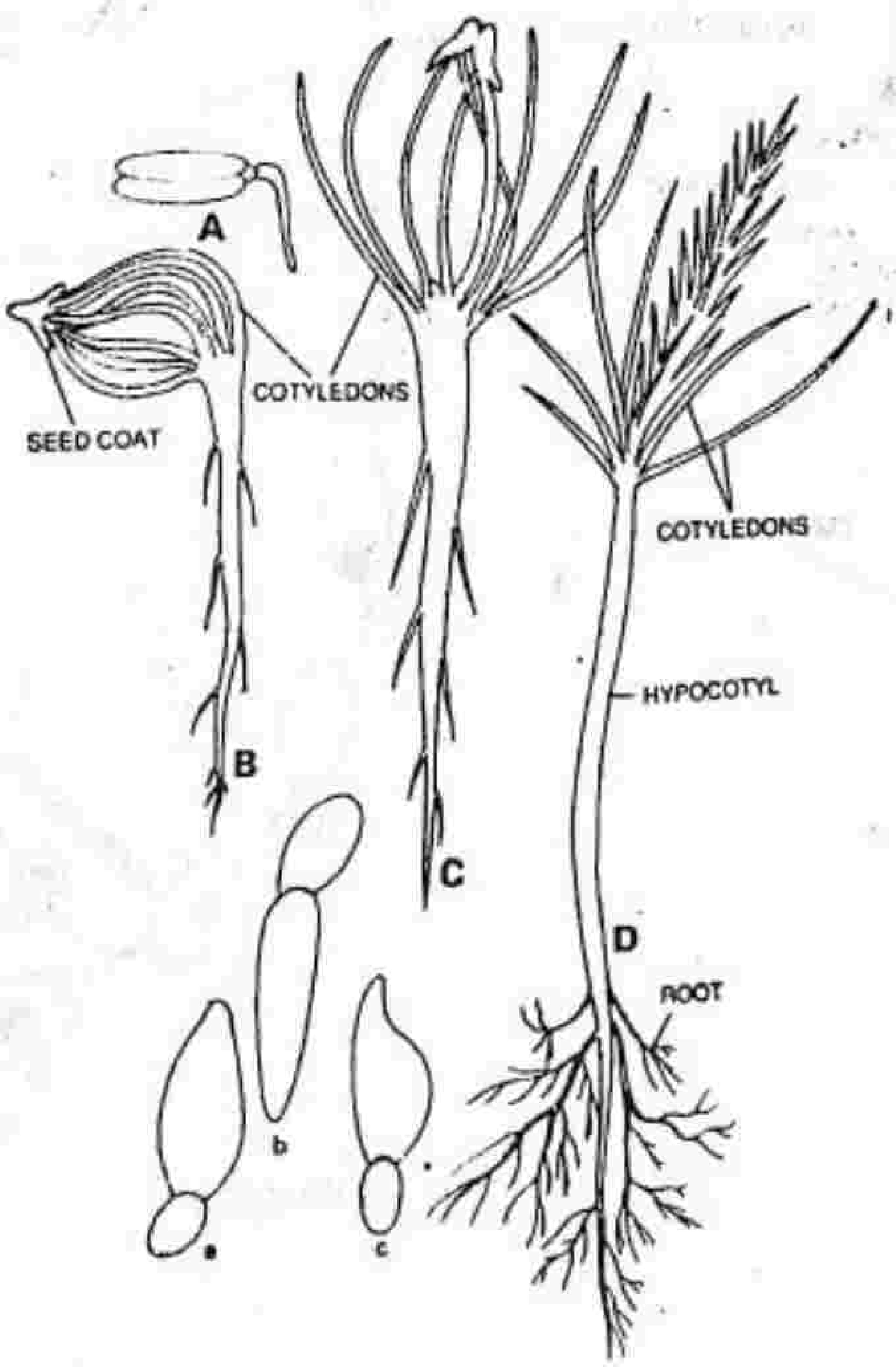


Fig. 8.25: Pinus— Seed and its germination.

Dispersal and Germination of Seed

A mature seed has a thin membranous wings derived from the surface of the ovuliferous scale that helps in dispersal of the seed by wind. When the seeds are mature, the cone axis elongates and the scales are separated. The seeds detach from the ovuliferous scale and are carried by wind.

The seeds germinate immediately after reaching a place suitable for their growth. The germination is epigean. The cotyledons remain within the seed for sometime and absorb food from the endosperm. Finally they emerge and function as first photosynthetic organs of the seedling. The plumule develops into primary shoot bearing spirally arranged needle-like leaves. Later the spur shoots arise in the axils of the some of the primary leaves.

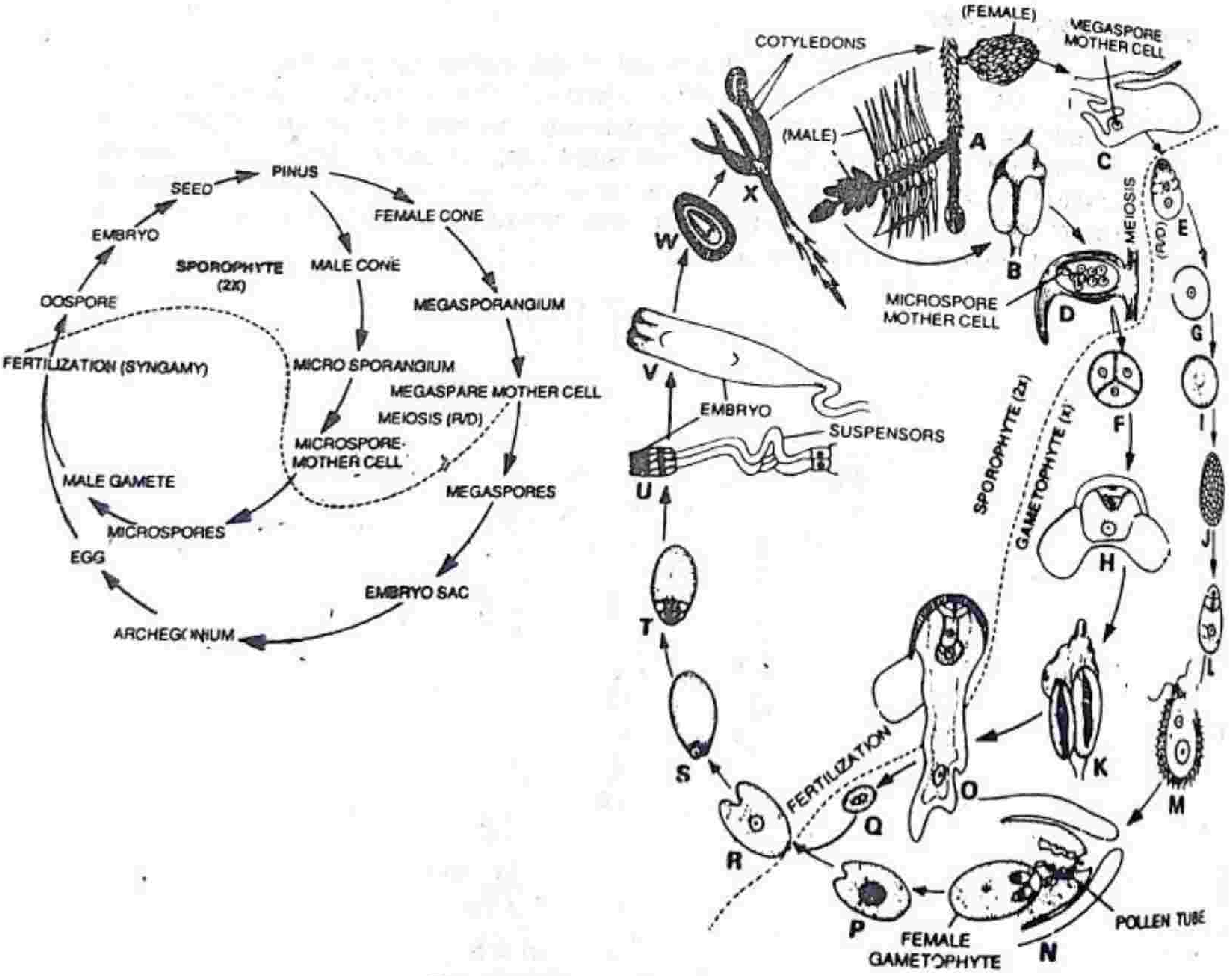


Fig. 8.26: Pinus— Life cycle.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are coniferales.
2. What is systematic position of pinus.
3. What is dwarf shoot.
4. What are needle leaves.
5. Draw structure of pollen grain of pinus.
6. What is male gametophyte.
7. How fertilization in pinus takes place.
8. Describe development of embryo.
9. Which types of vascular tissues found in pinus.
10. How seed developed ion pinus.

B. Long Questions

1. Describe life cycle of pinus.
2. Describe internal structure of leaf of pinus.
3. Describe internal structure of stem of pinus.
4. Write male and female cone of pinus.
5. Describe ovule of pinus and compare it with ovule of cycas.

GNETOPHYTA

Ephedra, Gnetum and Welwitschia are the three representatives of this division. These plants are sometimes considered to constitute a single order, the Gnetales. But careful morphological comparisons of these three genera indicate that there are a number of important differences among them, therefore each of the genera is placed in a separate order, with a single family in each. All these orders are placed in class Gnetopsida and division Gneotphyta in modern classification of gymnosperms.

The members of Gnetophyta are thought to represent a connecting link between the gymnosperms and angiosperms. The angiospermic features found in the members of Gnetophyta are:

i. The compound nature of both male and female strobili considered similar to the inflorescence of angiosperms.

ii. The presence of vessels in the xylem.

iii. The presence of two integuments in the ovule.

EPHEDRA

Systematic Position

Kingdom:	Plantae
Division:	Gnetophyta
Class:	Gnetopsida
Order:	Ephedrales
Family:	*Ephedraceae*
Genus:	*Ephedra*

Ephedra, also commonly known as joint fir, is usually a profusely branched shrub comprising of about 40 species. However, some species become tree-like and a few are climbers. Most species are found in arid or desert regions. *Ephedra foliata*, a scrambling shrub, is the common species found in the sub-continent. It is commonly met in forests near Lahore. Ephedra gerardiana is found along Himalayas at an altitude of about 3050 meters. *Ephedra intermedia* is a common inhabitant of Kashmir.

Vegetative Morphology

The young stem of Ephedra plant is green, ribbed and perform the function of photosynthesis. The older stems are hard, woody and branched. The shoots are jointed, have long internodes and arise in whorls usually. Intercalary meristem is present at the base of each internode. The shoots are shed during dry periods. The stems exhibit secondary growth. The leaves are reduced and scale-like. Each leaf consists of a thick midrib region and thin wings. The leaves are arranged in decussate manner usually, however in some species these develop in whorls of threes. The leaves of Ephedra are commonly united to form a basal sheath, and the shoot superficially resembles a branch of Equisetum. The plants are anchored to the substratum by a deep tap root and adventitious roots. Ephedra is dioecious, however monoecious species are also found.

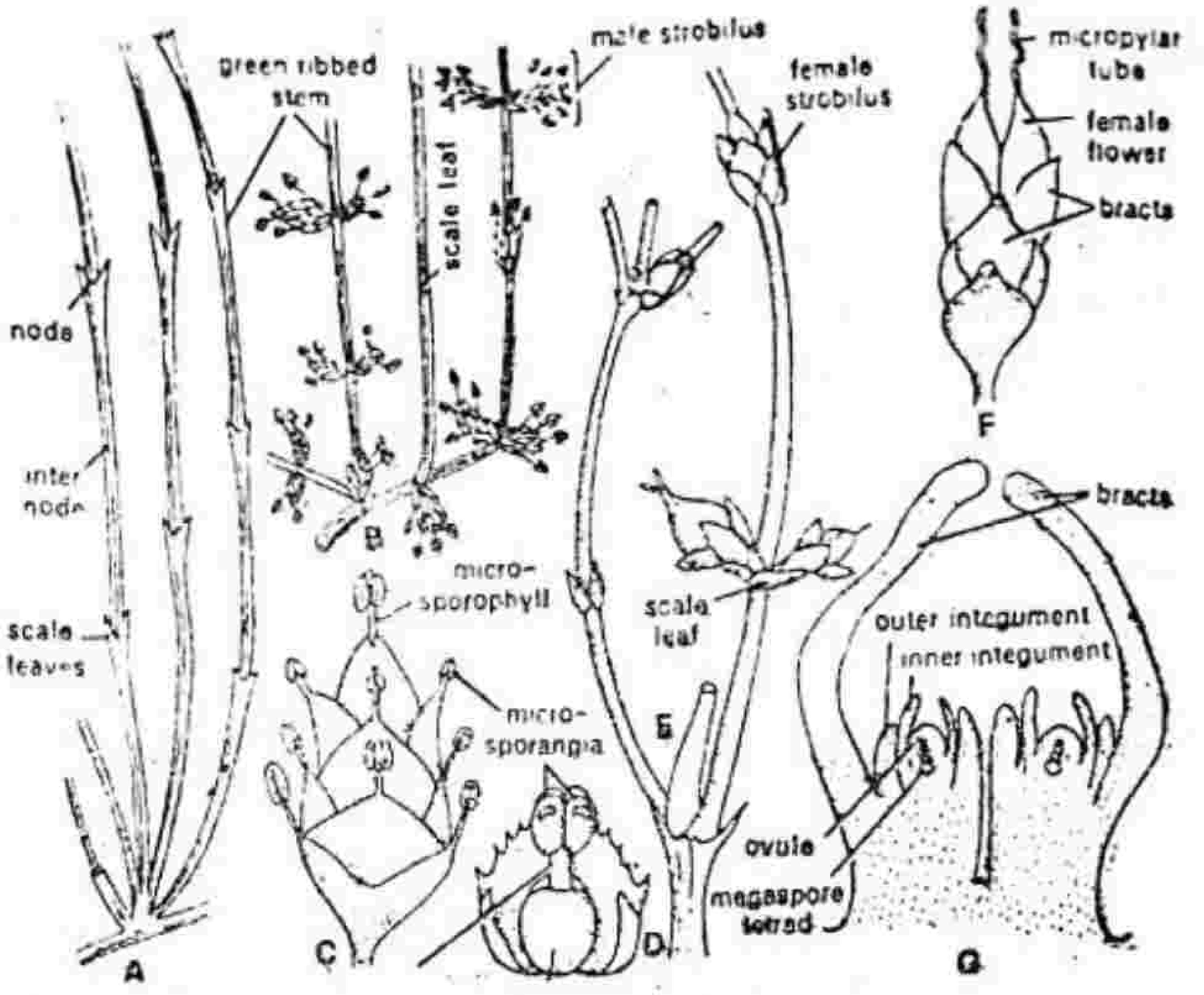


Fig. 8.27: Ephedra — Vegetative morphology: A-C. Male, female and sterile branches; D. Male strobilus; F. Female strobilus.

INTERNAL ANATOMY

The Root

The root is externally bounded by epiblema. Root hairs arise from the epiblema cells which help in absorption of water. Beneath it is the cortex which is differentiated into an outer region composed of thick-walled cells and an inner region formed of thin-walled cells. The innermost layer of cortex is differentiated into distinct endodermis. Next to endodermis is a single layered pericylce composed of thin walled cells. It surrounds diarch vascular tissue. The center of the root axis is occupied by a parenchymatous pith. Mucilage canals are present in the cortex.

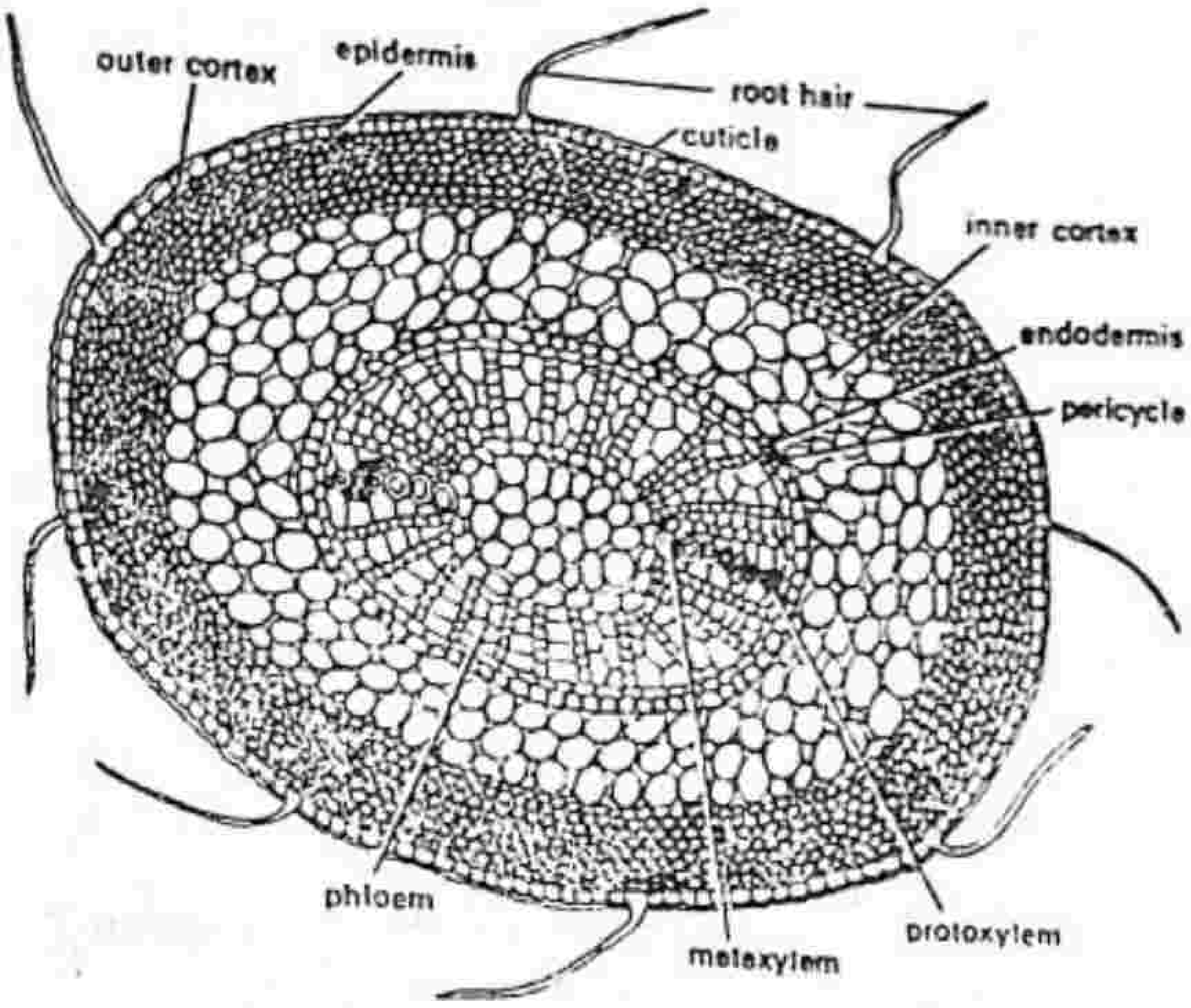


Fig. 8.28: Ephedra — Internal structure of root.

THE STEM

The stem is wavy in outline in a transverse section due to presence of ridges and furrows.

Epidermis

The outermost layer of cells is epidermis. It is single layered and consists of parenchymatous rectangular cells. The outer walls of epidermal cells are covered with a thick cuticle. Sunken stomata are present in the furrows.

Hypodermis

Beneath ridges patches of elongated sclerenchyma cells having thick lignified walls constitute the hypodermis that provides mechanical strength.

Cortex

Next to hypodermis is the cortex which is differentiated into two zones. The outer zone is composed of elongated, loosely arranged palisade-like cells that contain chloroplasts and are photosynthetic. The inner zone is formed of oval thin-walled cells resembling the mesophyll of the leaves. These cells also possess chloroplasts. Thus, the internal structure of cortex corresponds to a leaf.

Endodermis

The innermost layer of the cortex is differentiated into a well developed endodermis in young stems.

Vascular Tissues

The endodermis encloses vascular tissue as a definite pericylce is absent. The vascular tissue is present in the form of vascular bundles. Each vascular bundle is conjoint, collateral, endarch and open. The vascular cambium is single layered. The vascular bundles are arranged in a ring as in stems of dicot angiosperms. The spaces in between vascular bundles are occupied by parenchyma cells forming the medullary rays.

Xylem & Phloem

The xylem of a vascular bundles comprises of tracheids, vessels and xylem parenchyma. The vessels originate from pitted tracheids. The tracheids walls show annular or spiral thickening and contain bordered pits on their radial walls. The perforation plates of vessel members are foraminate and bordered pits are present on their lateral walls. Ephedra is the only gymnosperm species possessing vessels, an angiospermic anatomical feature. The phloem consists of sieve cells, phloem parenchyma and albuminous cells. The center of the stem is occupied by a parenchymatous pith.

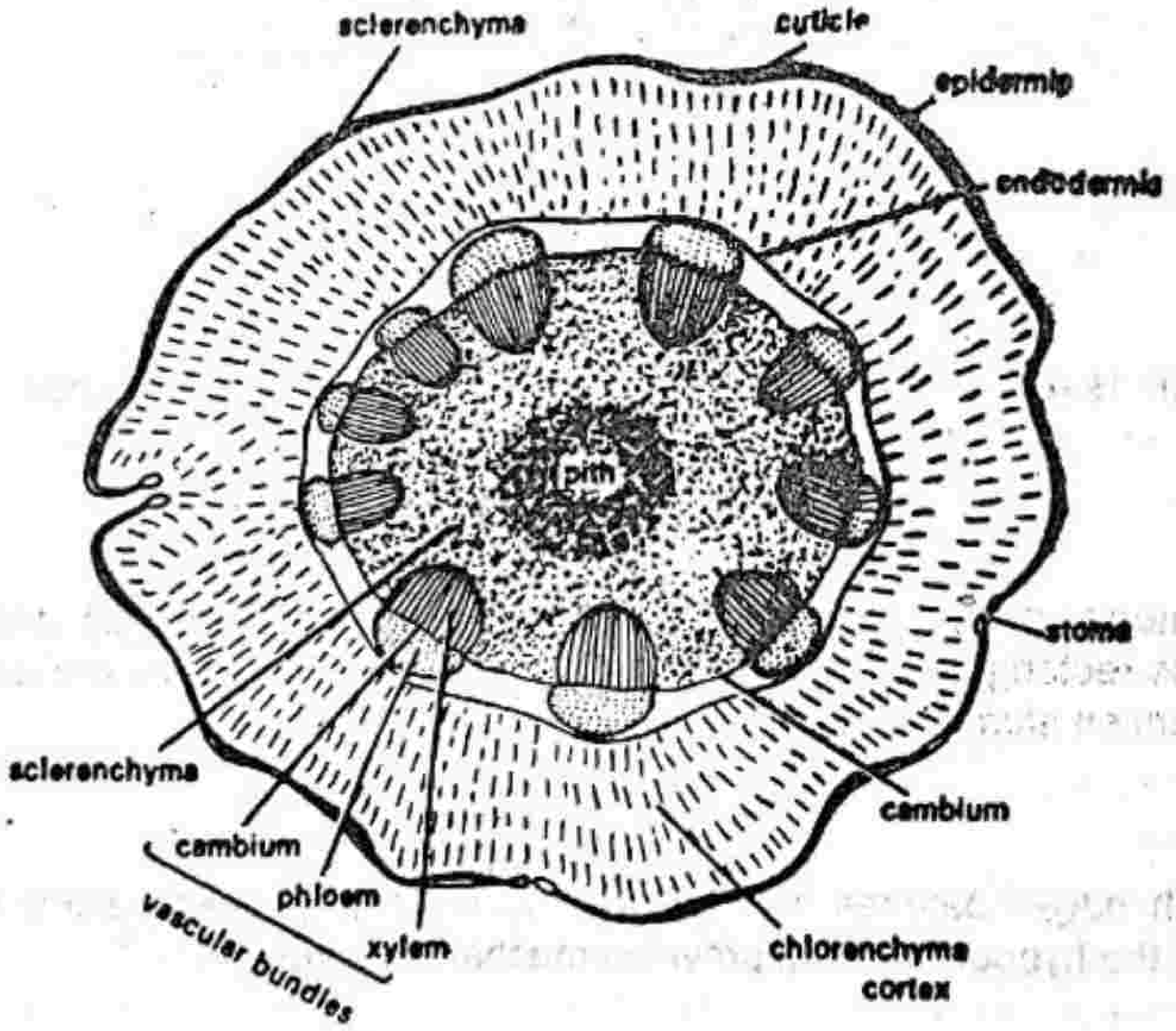


Fig. 8.29: Ephedra — Internal structure of stem.

Secondary Growth

Secondary growth is by the activity of cambium present in between xylem and phloem of a vascular bundle. Parenchyma cells present between vascular bundles become meristematic and join vascular cambium to form a cambium ring. Secondary vascular tissue is added in the form of distinct annual rings. More secondary xylem is produced than secondary phloem. Distinct secondary medullary rays are formed during secondary growth. The most significant feature of the secondary xylem is formation of vessels by proliferation of terminal walls of some of the tracheids.

The Leaf

The internal structure of the leaf is simple. It is oval in outline in a transverse section bounded by a single layered epidermis composed of radially elongated parenchyma cells. The epidermis is covered with a thick cuticle. A single stoma is observed in the epidermis. Beneath the epidermis loosely arranged oval cells containing chloroplasts are arranged in many concentric layers. The center of the leaf is occupied parenchyma in which two vascular bundles are embedded.

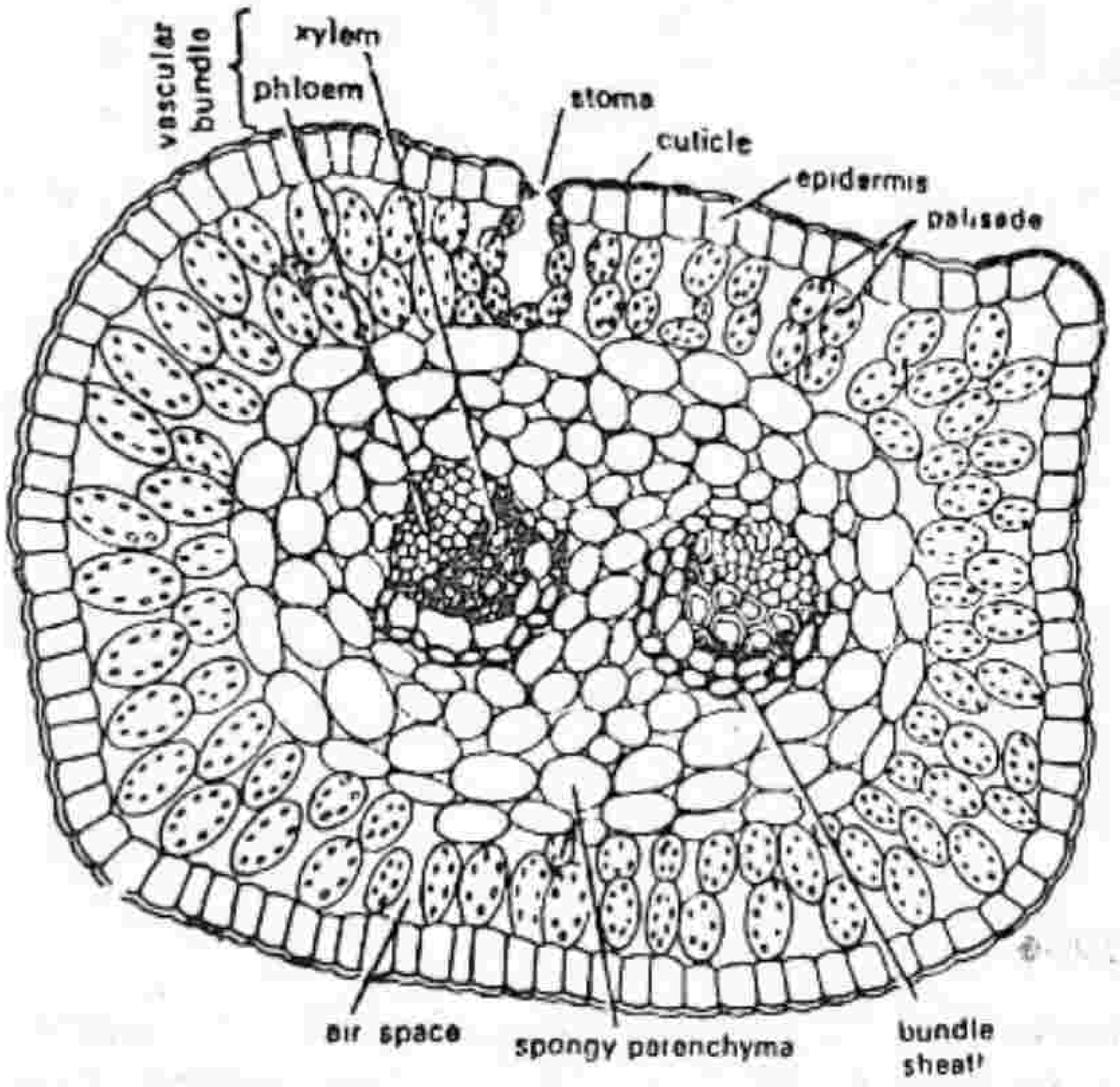


Fig. 8.30: Ephedra — Internal structure of leaf.

Reproduction

The Ephedra plant is a sporophyte and both monoecious and dioecious species are known, however most species are strictly dioecious. The male and female cones develop on different plants. Because of superficial resemblance of the reproductive structures of Ephedra to those of angiosperms, these are sometimes referred to as inflorescences or flowers.

The Cones

Both, the male and female cones are compound structures, i.e., the cone axis bears pairs of bracts which bear either sporangia bearing or ovulate shoots in their axils.

Male Cone

The male cones have rounded apices. Each cone consists of a main axis upon which a number of pairs of bracts are arranged decussately. The lowest pair of bracts is sterile. The upper bracts bear a microsporangiate shoot in their axils. Each microsproangiate shoot consists of a pair of fused bracteoles (also called perianth) and a short axis or column ending in 8-12 microsporangia. The column elongates at the time of pollination and carry the microsporangia free of bracteoles and subtending bracts.

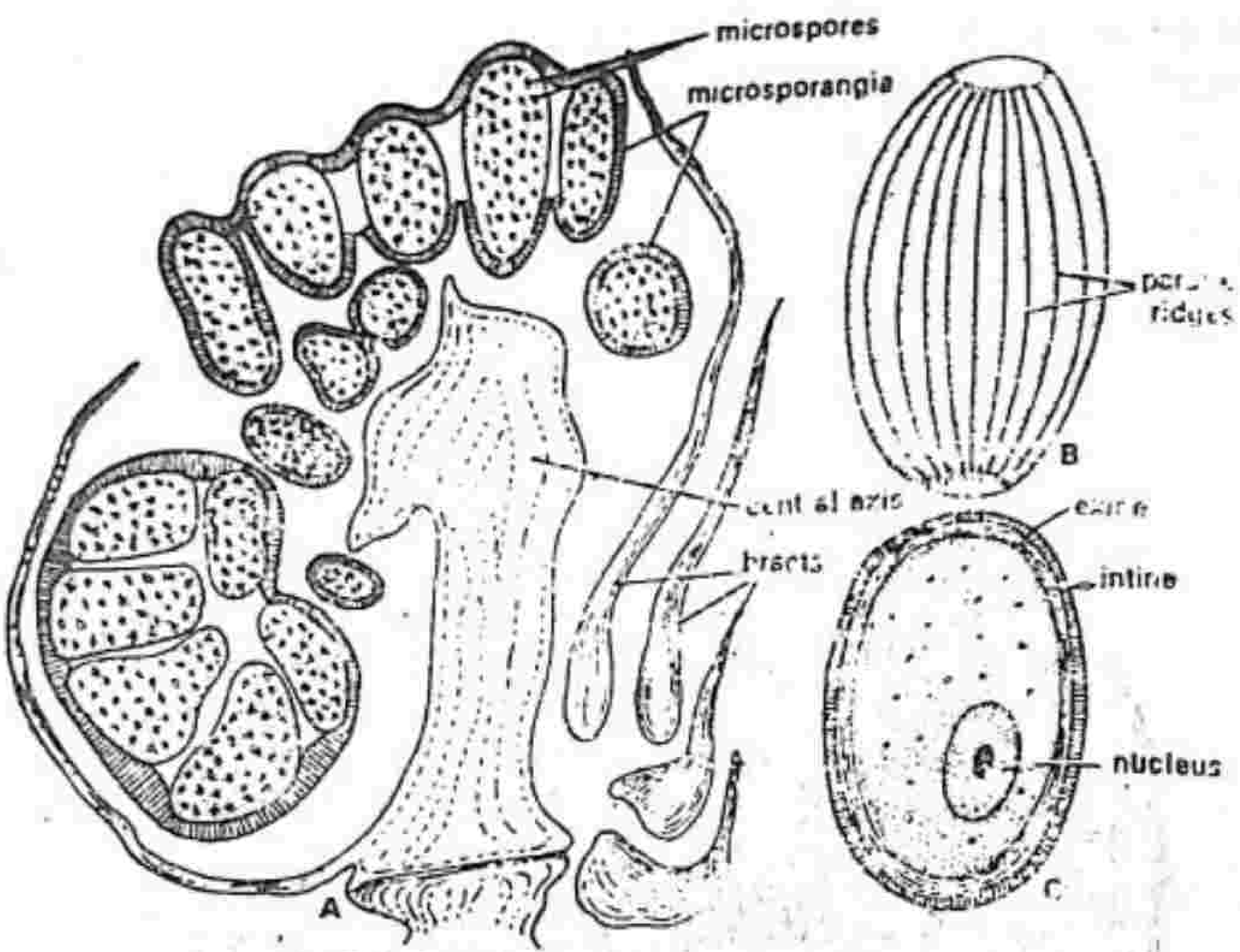


Fig. 8.31: Ephedra — Section through a male strobilus and pollen grains.

Structure and Development of Microsporangium

A young microsporangium has 2-layered wall, the outer wall layer being epidermis; and a prominent nutritive layer, the tapetum, surrounding the sporogenous tissue. The sporangium dehisces by formation of an apical slit in the sproangium wall.

The sporangium initial is hypodermal. After brief growth the initial is separated into two groups by appearance of a band of sterile cells, and the microsporangium becomes biloculate. The sporangial initial divides by periclinal division to produce an outer primary wall cell and an inner primary sporogenous cell. The primary wall cell functions directly as outer wall layer or epidermis of sporangium. The cells of this layer becomes flattened and stretched. The primary sporogenous cell divides periclinally twice to produce inner layer of sporangium wall and tapetum. The tapetal cells become multinucleate and degenerate. The sporogenous cells undergo repeated divisions to form archesporium. The inner wall layer is crushed at this stage. The archesporial cells divide and their last generation is the microspore mother cells. Each microspore mother cell divides by meiosis to produce a tetrahedral tetrad of microspores.

Female Cone

The female cone is an elliptical structure with a pointed apex. It consists of an axis on which decussately arranged bracts are present. Most of these bracts are sterile. The upper two bracts bear an ovule in their axils on short stalks. The ovule of Ephedra is unique among the gymnosperms due to presence of two integuments. The integuments surround a parenchymatous nucellus.

The evidence from ontogeny and vascular anatomy indicates that the outer integument is equivalent to a pair of fused appendages and is not an integument in a strict sense. The ovule of Ephedra is present on a greatly reduced basal megasporophyll and is enveloped by a pair of fused bracteoles which are homologous with the bracteoles of the microsporangiate shoot. Thus, the female cone is a compound structure.

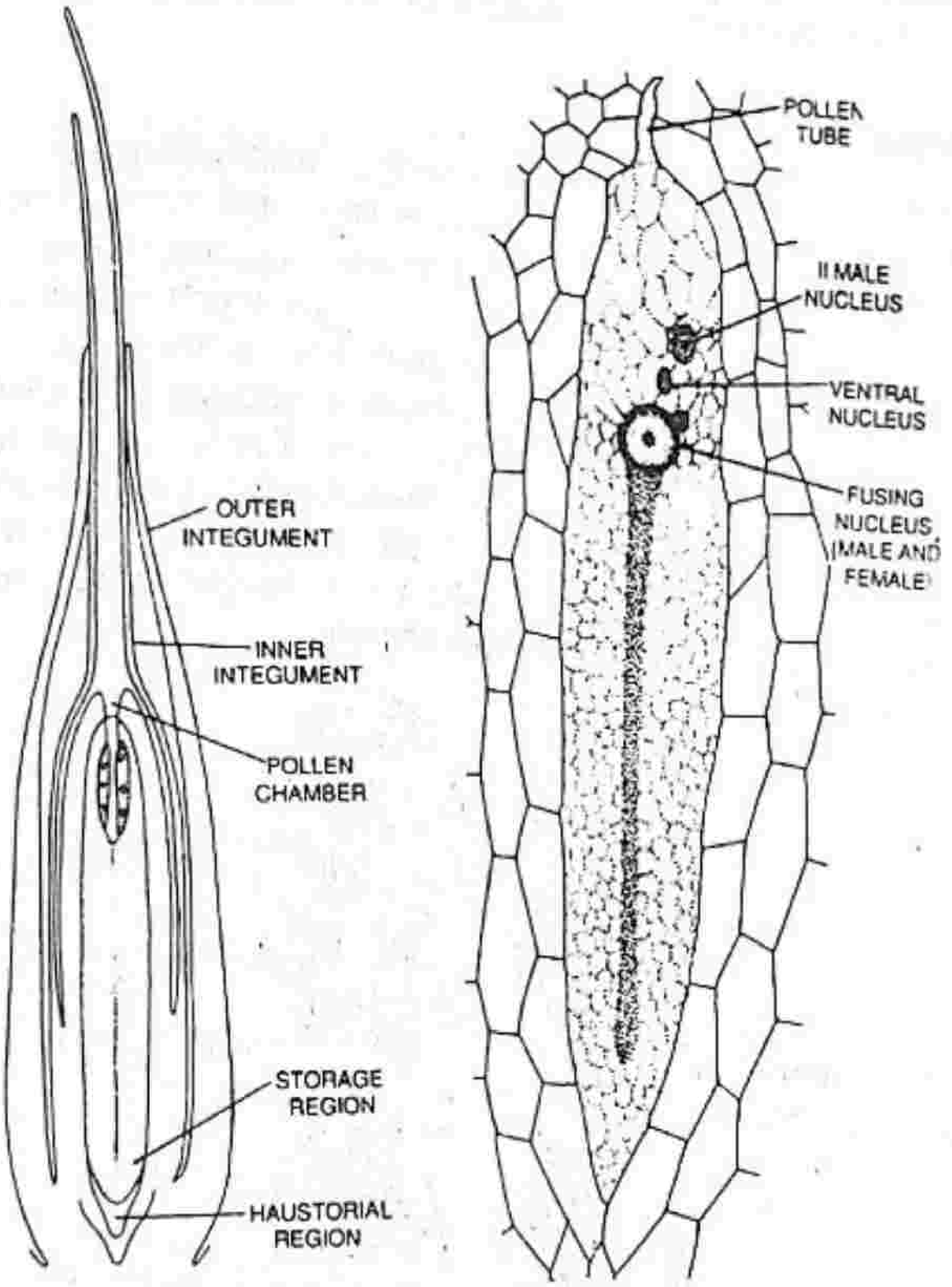


Fig. 8.32: Ephedra — Section through female strobilus and structure of an ovule.

The Ovule

A young ovule consists of a well-developed nucellus enveloped by a fleshy cup-like structure, usually referred to as outer integument; and an inner delicate inner integument. The outer integument is attached to the base of the ovule and free above. The inner integument is prolonged into a tubular structure that projects beyond the bracts and bracteoles at the time of pollination. The cells of inner integument contain chloroplasts at the time of pollination.

The nucellus contains a hypodermal archesporial cell. It divides periclinally to produce an outer parietal cell and an inner megaspore mother cell. The parietal cell produces many cells by repeated periclinal divisions so that the megaspore mother cell is pushed deep within the tissue of the nucellus. Meiotic divisions in megaspore mother result in the formation of a linear tetrad of megaspores. Usually the lowest megaspore is functional and it enlarges and produces the female gametophyte.

The Gametophytes

The microspores and megaspores germinate into male and female gametophytes respectively. The male gametophyte is endosporic, i.e., the microspores start their development before they are shed from the microsporangia.

Male Gametophyte

The microspores are ovoid, longer than their width. These are surrounded by an outer thick layer, the exine and an inner delicate layer, the intine. The exine is provided with parallel ridges. The nucleus of the microspore migrates to one of the pole before germination. It divides to produce prothalial cell nucleus which is demarcated by a wall to form a small first prothalial cell lying near the pole. The nucleus of the larger cell divides again mitotically to produce a small second prothalial nucleus and a larger nucleus. The second prothalial nucleus is not surrounded by a wall. The larger nucleus divides to form generative and tube nuclei. The generative nucleus divides to form a stalk nucleus and a body nucleus. All these nuclei are not surrounded by a definite wall but are separated by cytoplasmic sheaths. At this 5-nucleate stage the semi-germinated male gametophyte now called pollen grain is shed from microsporangium.

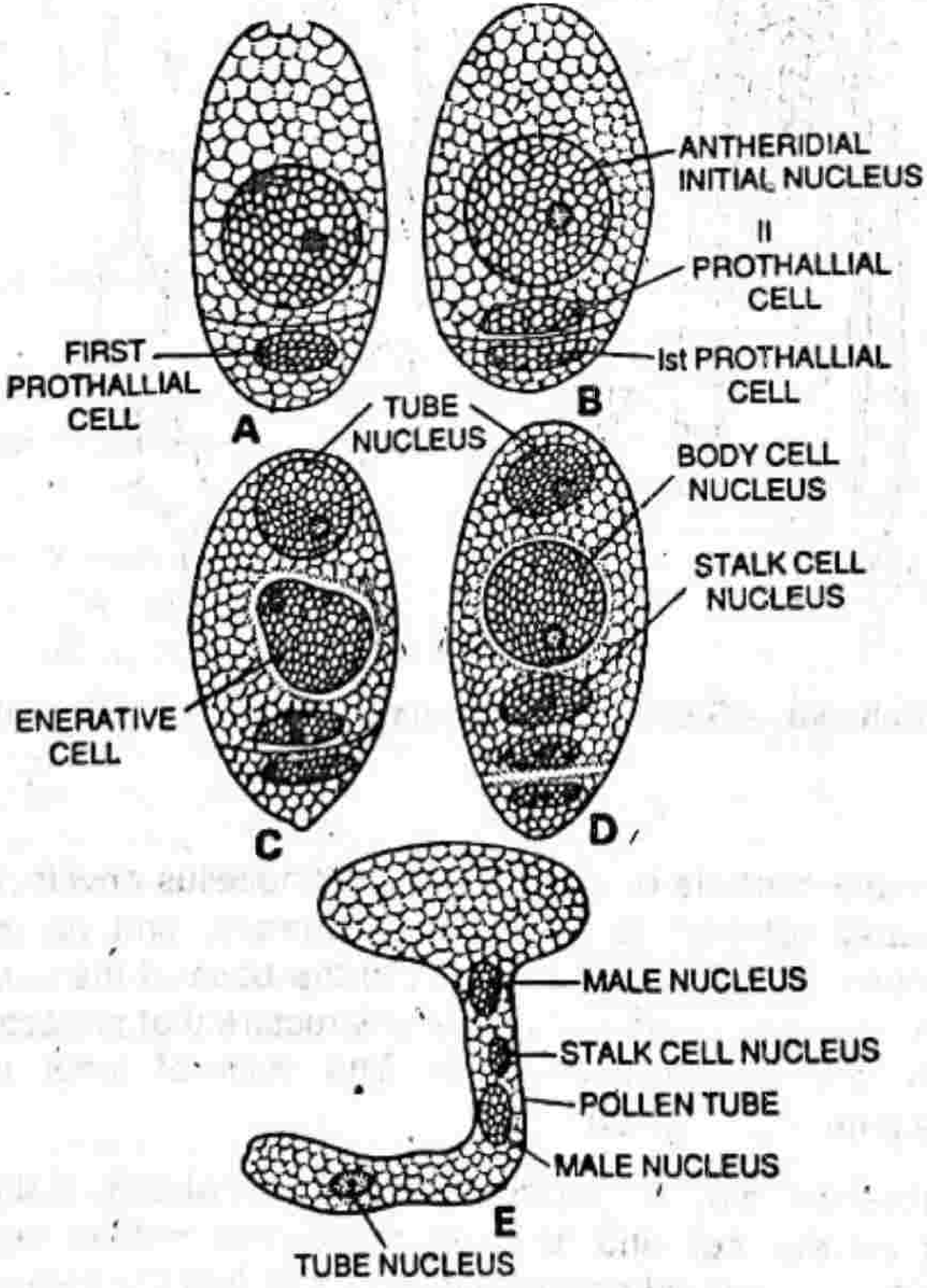


Fig. 8.33: Ephedra — Development of female gametophyte.

Further development of male gametophyte takes place after pollination. Within the pollen chamber the exine of the microspore is shed and pollen tube emerges. The body cell nucleus divides to form two male nuclei which may be slightly unequal in size. The tube nucleus and the male nuclei migrate into the pollen tube.

Female Gametophyte

The female gametophyte develop by free nuclear division of the megaspore nucleus. The nucleus of functional megaspore divides and both nuclei move towards opposite poles by formation of a central vacuole. These polar nuclei divide to produce 16 nuclei which arrange themselves at the periphery of central vacuole. The nuclear division continues and central vacuole start disappearing due to growth of the cytoplasm. Finally the vacuole disappears and the nuclei are distributed evenly in the enlarged megaspore. The wall formation is centripetal and continues until the gametophyte becomes cellular.

The chalazal cells of the female gametophyte are dense and filled with stored food, and those at micropylar end are watery and vacuolated. The cells of lower zone act as nutritive tissue whereas archegonia develop from the cells of micropylar zone.

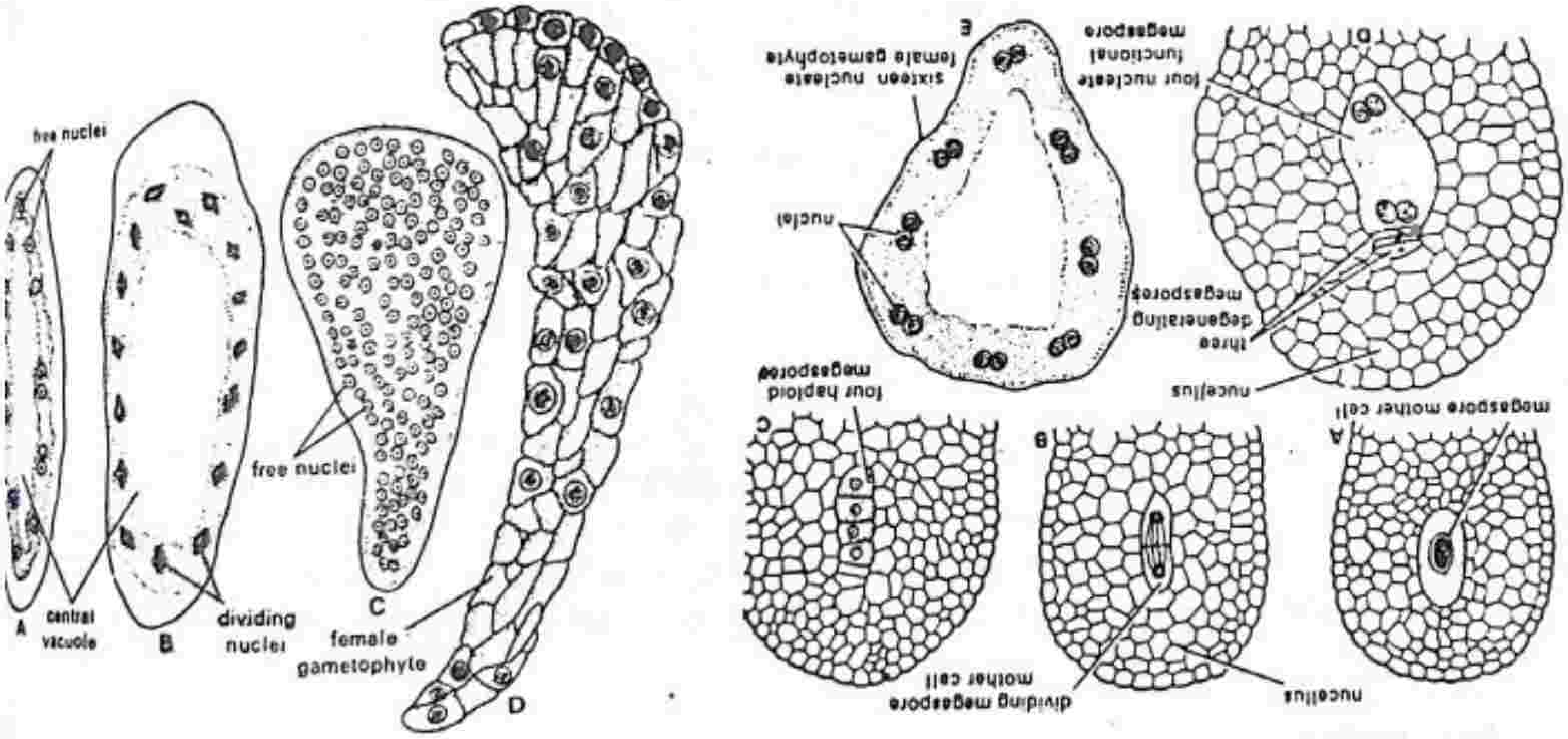


Fig. 8.34: Ephedra — Development of female gametophyte.

Structure and Development of Archegonium

The number of archegonia range from one to three. The archegonium arises from a superficial cell at the micropylar end of the female gametophyte. The archegonial initial divides periclinally into an outer primary neck cell and an inner central cell. The primary neck cell undergoes repeated periclinal and anticlinal divisions to produce as massive neck consisting of 30-40 cells arranged in tiers of four or more. The central cell enlarges and its nucleus divides to form a ventral canal nucleus and the egg nucleus. These nuclei are rarely separated by walls. The gametophyte cells surrounding the central cell form a one or two layered jacket. The walls of jacket cells are thin and the cells may be binucleate.

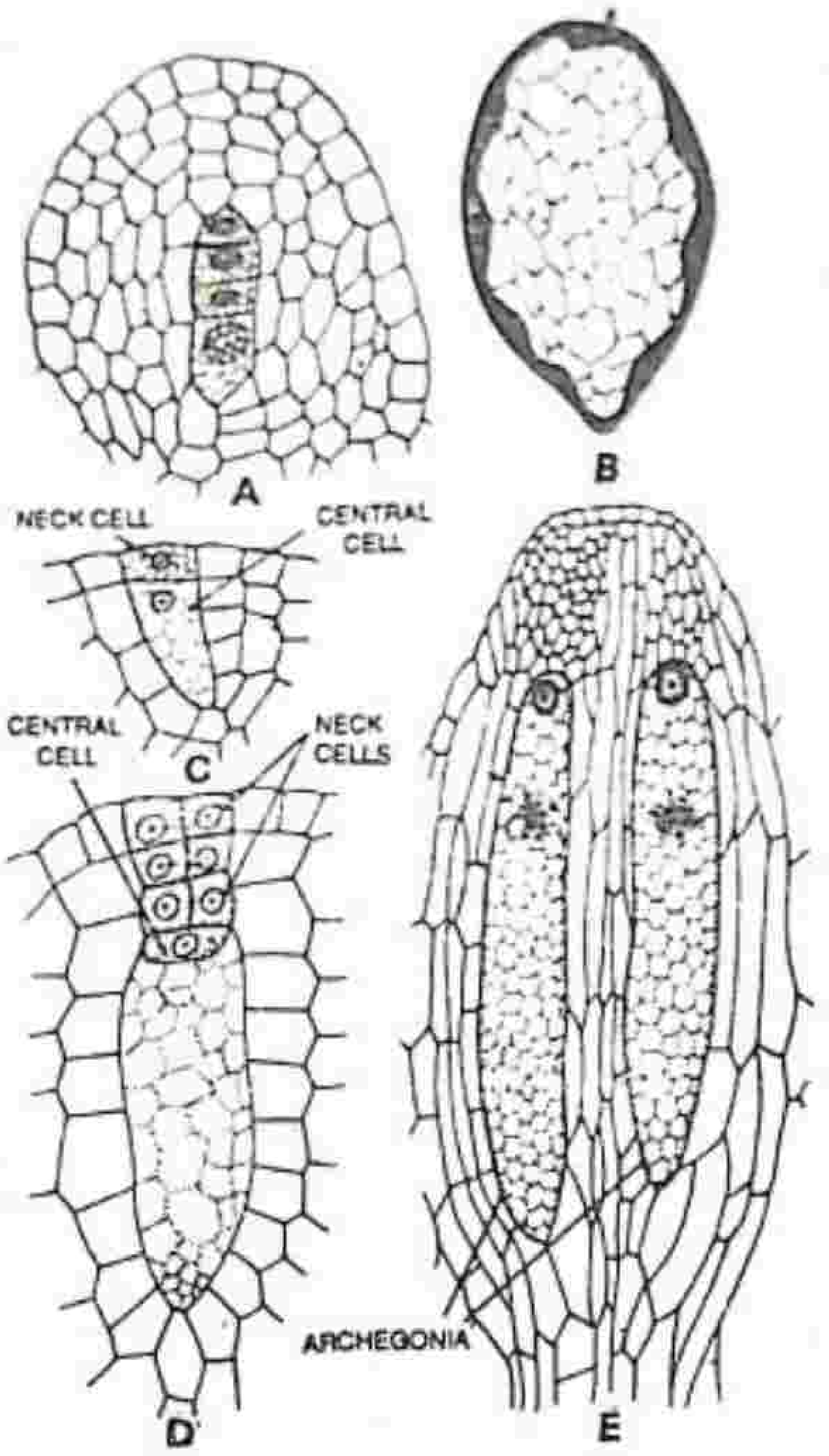


Fig. 8.35: Ephedra — Structure and development of archegonium.

Pollination

Pollination occurs through the agency of wind. The nucellar tissue lying above female gametophyte becomes disorganized during early stages of development of archegonia, to produce pollen chamber where the pollens are lodged after pollination. A pollination droplet is present at the tip of the ovule which draws the pollens caught in it into the pollen chamber. Many pollen grains are present in the pollen chamber of each ovule.

Fertilization

The pollen tube grows down between the neck cells and reaches the egg nucleus and discharges the male nuclei into it. One of the sperm nucleus moves towards the egg nucleus and unites with it to form zygote nucleus. The second male nucleus is reported to fuse with the ventral canal nucleus to effect a double fertilization, but this requires confirmation.

Embryo Development

Embryo in Ephedra develops by free nuclear division as in other gymnosperms. The zygote nucleus undergoes three successive divisions to form eight nuclei. These nuclei are unequal in size and scattered in the egg cytoplasm. They become surrounded by delicate walls formed by free-cell formation to produce proembryos. Each of these can develop into an embryo independently, therefore Ephedra exhibits a distinct cleavage polyembryony. All the proembryonal cells begin to develop into embryos, but lower proembryonal cells develop more rapidly, however only one reaches maturity, the others disintegrate.

The proembryonal cell produces a tubular projection called suspensor tube. The nucleus of the proembryonal cell migrates to the tip of this tube and divides. The two nuclei become separated by a transverse wall and the embryo now consists of two cells. The terminal embryo initial and the elongating suspensor cell. The embryo initial divides by a periclinal division into an upper and a lower cell. The lower cell divides further by longitudinal division into two cells. These three cells divide further by repeated divisions to produce the embryo proper. Elongating primary suspensor pushes the embryo into the vegetative tissue of the female gametophyte. The embryo cells absorb nutrients and grow into a mature embryo. The upper end of the embryo next to suspensor cell differentiates into secondary suspensor, and the lower end of the embryo produces two cotyledons and the shoot apex.

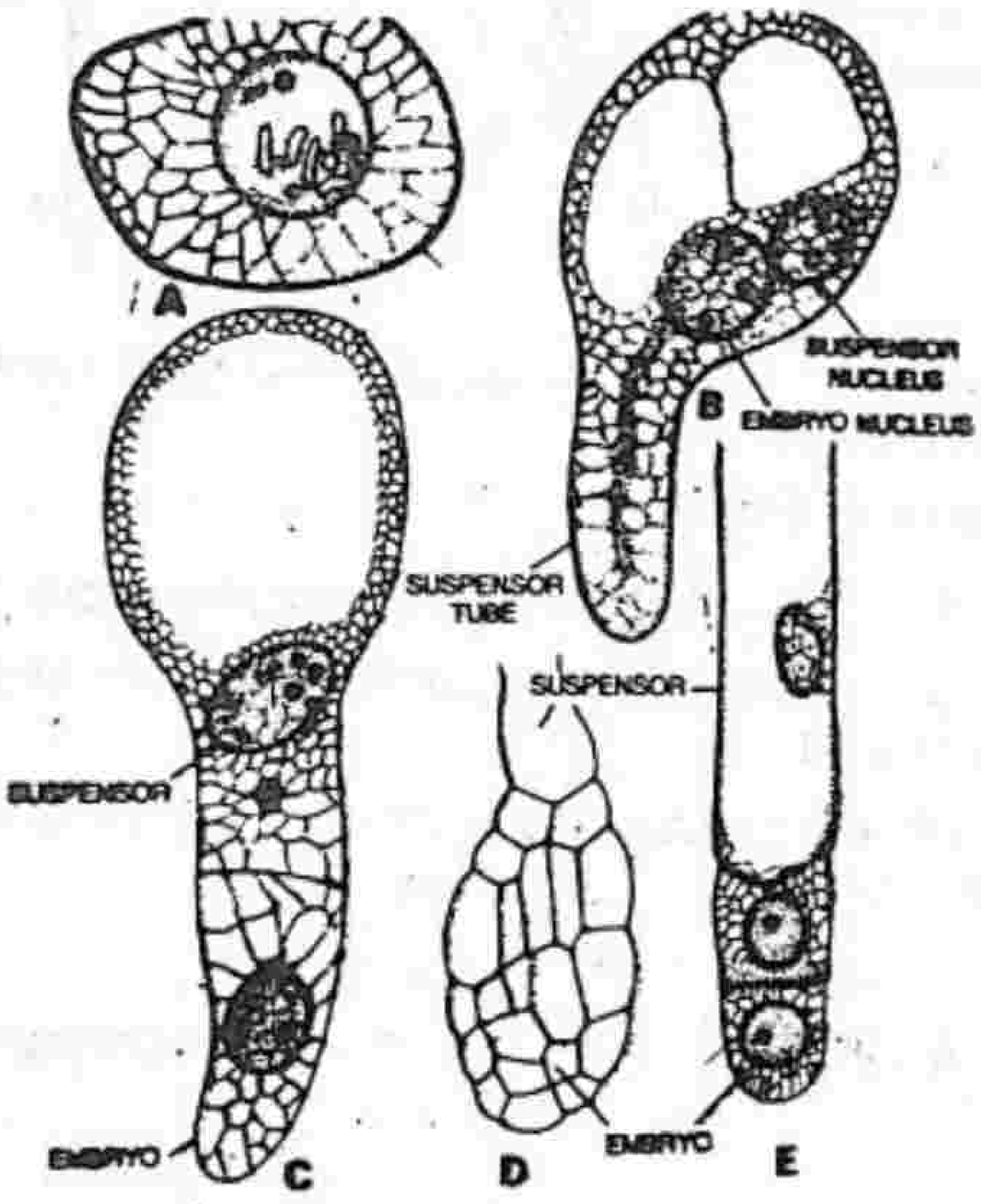


Fig. 8.36: Ephedra — Development of embryo.

Just after fertilization, when the proembryos are developing, certain cells at the micropylar region of the female gametophyte are stimulated to divide, they form a plug, which closes the pollen chamber of the ovule.

Seed — Development, Structure and Germination

As the embryo becomes dormant, the inner integument forms a hard seed coat. The subtending adjacent bracts of the female cone become thick and fleshy, forming an additional layer around the seed coat. A mature seed consists of two large cotyledons embedded within the tissue of female gametophyte, and remains of nucellus in the form of a disorganized sheath of cells. The germination of seeds is epigeal and the two cotyledons are long-persistent and photosynthetic.

SOME IMPORTANT QUESTIONS

A. Short Questions

1. Name members of Gnetophyta.
2. Give general characters of Gnetophyta.
3. What is the nature of strobili.
4. Describe systematic position of ephedra
5. What is the importance of sclerencyma in the stem of ephedra.
6. Which type of stele found in ephedra.
7. Draw ovule of ephedra.
8. What are the economic importance of ephedra.

B. Long Questions

1. Write general character of gnetophyta.
2. Describe economic importance of ephedra.
3. Describe internal structure of stem of ephedra.
4. Write male and female cone of ephedra.
5. Describe ovule of ephedra and compare it with that ovule of pinus.
6. Describe life history of ephedra.
7. Describe sexual reproduction in ephedra.

SECTION X

ANGIOSPERMS

Chapter 9

THE ANGIOSPERMS

ANGIOSPERMIC PLANT BODY

An angiospermic plant consists of vegetative organs: the root, stem, branches and leaves; and reproductive organs: the flowers. The vegetative organs are meant for absorption of water and minerals (raw materials), manufacture of food, and its utilization for growth and development. In some cases the vegetative organs are used for vegetative reproduction. The reproductive organs or flowers vary in size, form and colour from species to species.

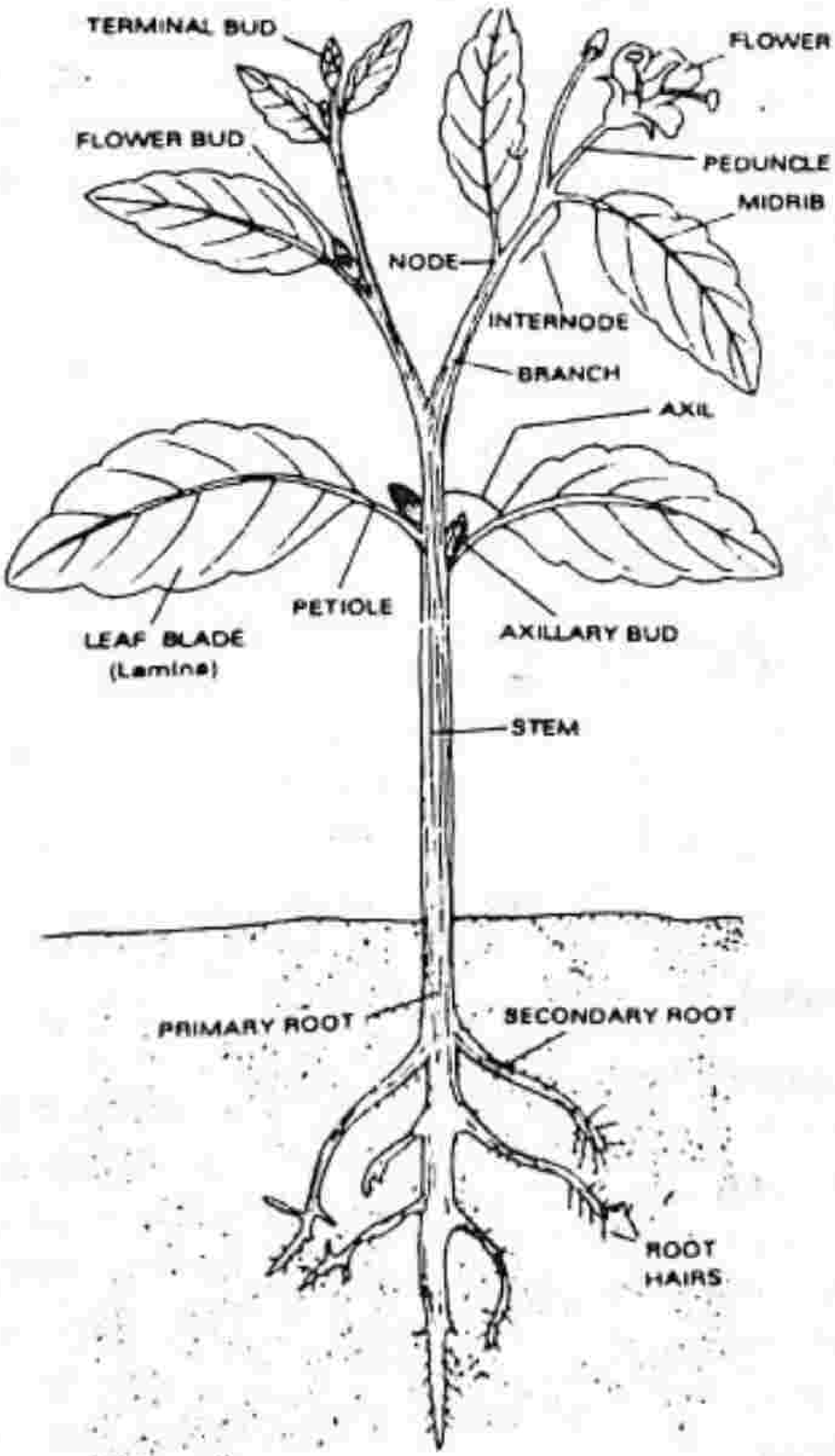


Fig. 9.1: A typical plant.

THE SPOROPHYTE

The angiospermic plant is diploid (2n) and a sporophyte. It is the dominant phase of the life cycle. It produces two morphologically and physiologically different kinds of spores, the microspores and megaspores. The reproductive structures are flowers.

Structure of a Typical Flower

Each flower consists of four types of floral leaves: the sepals, petals, stamens and carpels, arranged in whorls on thalamus or receptacle. The sepals and petals are together termed perianth.

The stamens (microsporophylls) and carpels (megasporophylls) are highly modified reproductive foral leaves of the flower in which spores are produced.

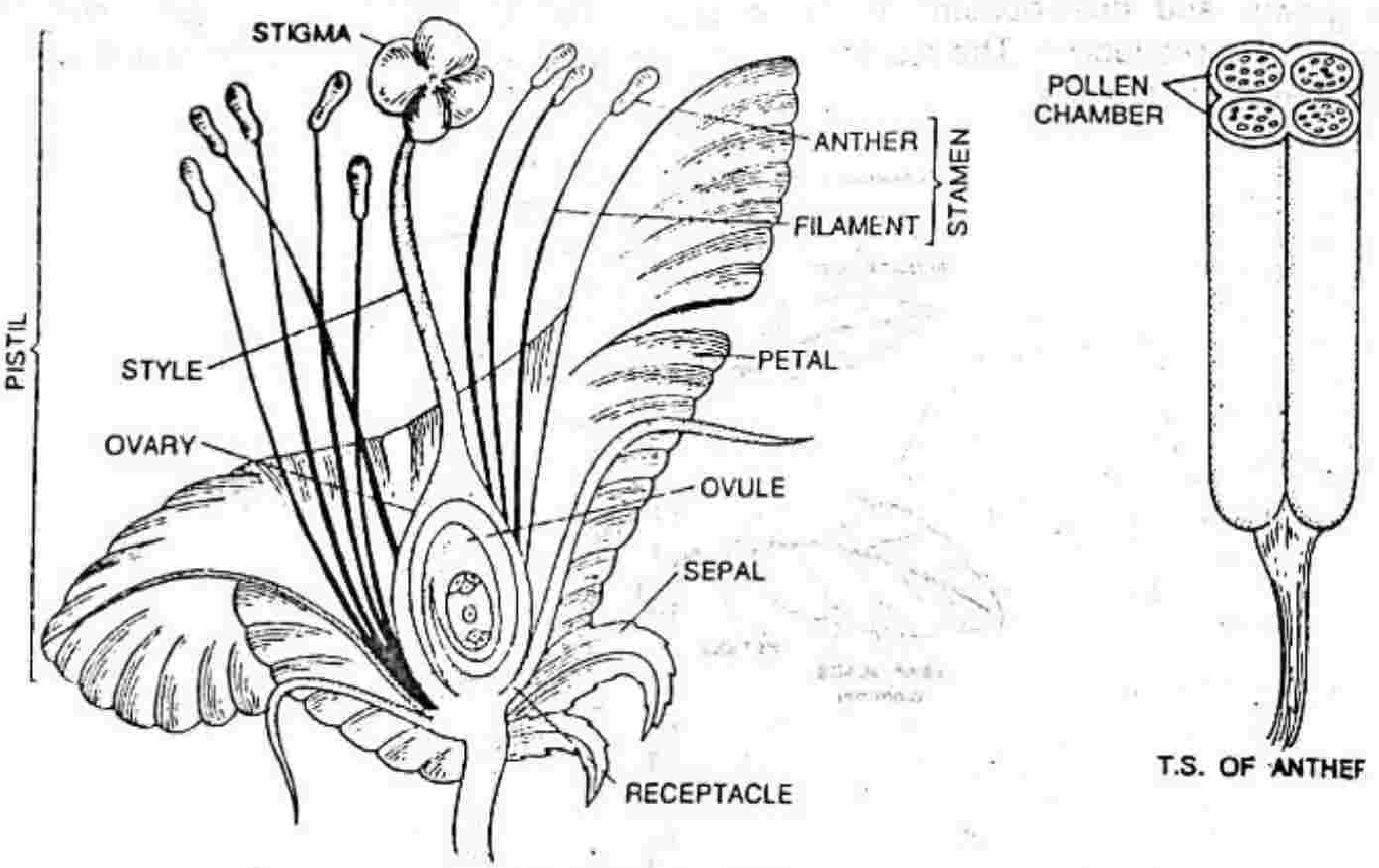


Fig. 9.2: L.S. of Flower.

Microsporophyll (Stamen)

Each microsporophyll or stamen consists of a stalk, the filament, and a bilobed structure at its tip, the anther. The anther lobes are connected with a tissue, the connective. Each anther lobe contains two microsporangia in which microspores develop. Each microsporangium is surrounded by a many-layered sporangium wall that surrounds sporogenous cells. The innermost layer of sporangium wall is nutritive in nature and called tapetum. The sporogenous cells divide to give rise to microspore mother cells which undergo meiosis to produce tetrads of microspores. The microspores germinate to produce male gametophyte.

Microspore

Each microspore is unicellular, uninucleate structure possessing two layered wall. The outer layer is thick, cuticularized and called exine and inner is thin and known as intine. The exine contain one or more thin places, the germ pores. The exine is provided with spinous outgrowths, warts or reticulations in some cases.

Megasporphyll (Carpel)

Each megasporophyll or carpel consists of a basal swollen part, the ovary; a stalk usually present at the top of the ovary, the style; and stigma, the variously modified tip of the style. The stigma is the receptive disc and receive pollen grains.

Ovule

The ovary contains one or more rounded or oval bodies, the ovules. The ovules are borne on the ovary wall upon a specialized tissue, the placentae (singular=placenta).

Each ovule is attached to the placenta through a short stalk, the funicle. The place of attachment of the funicle with the main body of the ovule is hilum. The main body of the ovule consists of sporogenous tissue, the nucellus, surrounded by one or two proetective coverings, the integuments. The integuments do not surround the nucellus completely rather a small opening called micropyle is left at the top. The junction of the nucellus and integument is known as chalaza. Nucellus represents megasporangium, therefore the ovule is also termed integumented megasporangium.

A nucellus cell enlarges in size and acts as megaspore mother cell. It divides meiotically to produce a linear tetrad of megaspores. The upper three megaspores disintegrate usually and the remaining one enlarges to form embryo sac or female gametophyte.

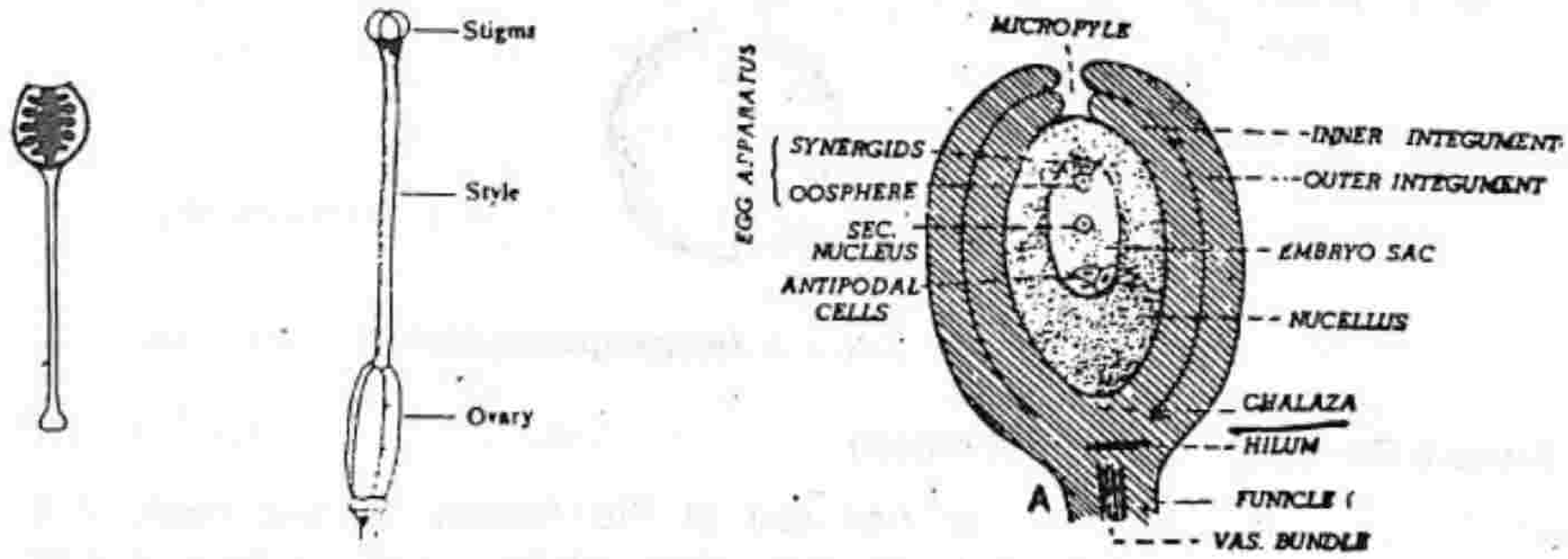


Fig. 9.3: L.S. of ovule.

THE GAMETOPHYTE

The gametophyte phase of angiosperms is haploid, much reduced and dependent upon sporophyte. The microspores and megaspopres develop into male and female gametophytes respectively.

Male Gametophyte

The microspore is the first cell of the male gametophyte. The male gametophyte is represented by pollen grain (semi-germinated male gametophyte) and pollen tube with two sperm nuclei and a tube nucleus.

The germination of the microspore starts while it is still in the microsporangium. The nucleus divides to form a generative nucleus and a vegetative nucleus. The intine grows out through germ pore to form pollen tube. At this semi-germinated condition the microspore, now called pollen grain, move out of the microsporangium and is carried to the stigma of the carpel by wind, water, insects or animals. This transference is called pollination. The pollen grain completes rest of germination there. The generative nucleus divides into two to form sperm nuclei, and the pollen tube elongates and carry the sperm nuclei to the egg cell.

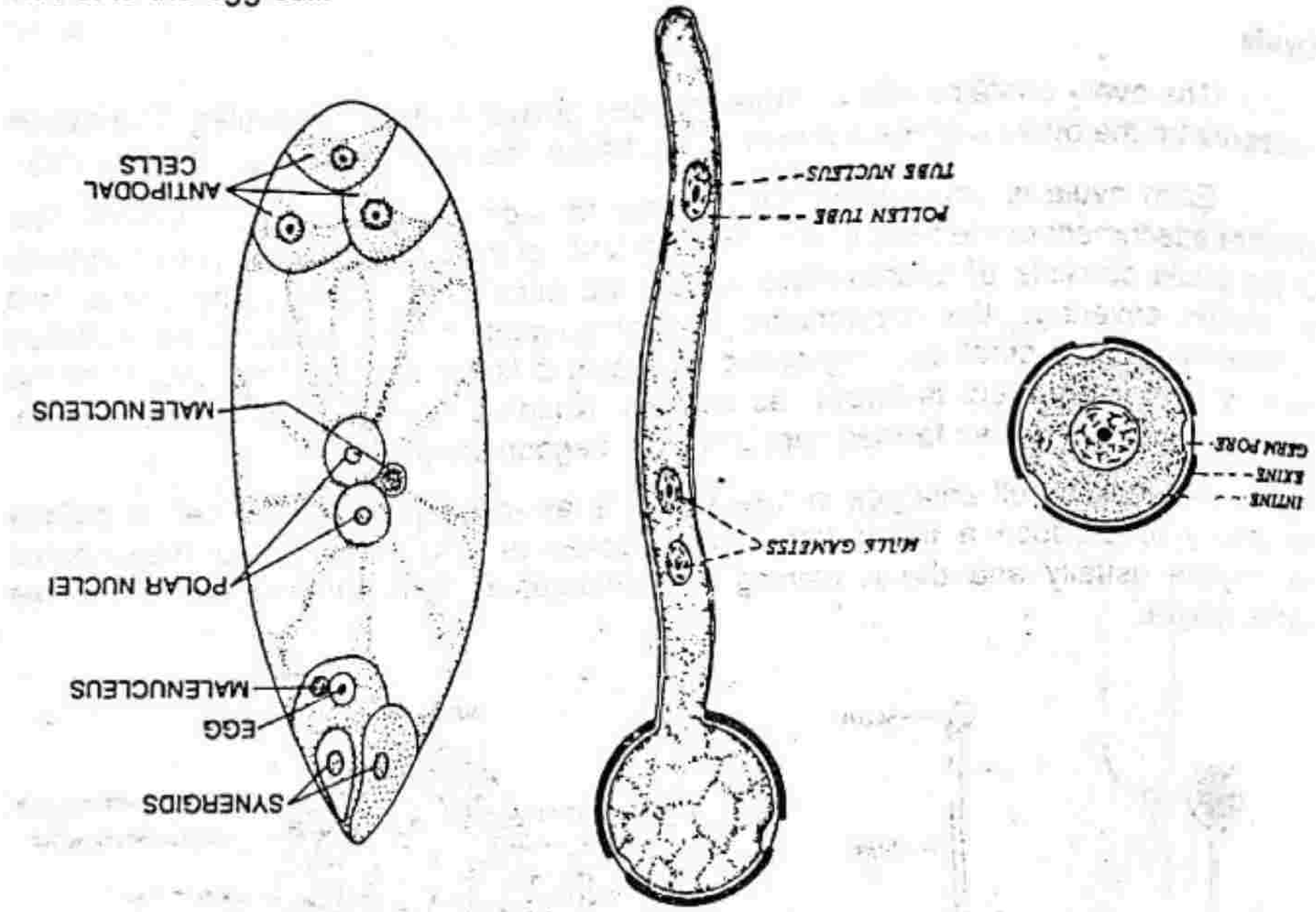


Fig. 9.4: Male and Female gametophyte.

Female Gametophyte (Embryo Sac)

The megaspore is the first cell of the female gametophyte. The female gametophyte is represented by eight-nucleate embryo sac. A typical embryo sac (Polygonum type) contains an egg apparatus comprising of an egg cell and two synergids or help cells at micropylar end; three anitpodal cells at chalazal end; and a diploid secondary nucleus in the center.

DOUBLE FERTILIZATION

Fertilization in angiosperms is unique. It is double fertilization. One of the two sperm nuclei fuses with egg cell to form zygote nucleus which develops into embryo, and the other fuses with secondary nucleus to form primary endospermic nucleus which give rise to nutritive tissue, the endosperm. The fertilized egg secretes a thick wall and is transformed into oospore, the first cell of the sporophyte. It divides into a basal suspensor cell and a terminal embryo cell which develops into an embryo.

THE EMBRYO

The embryo in dicots is octant type and comprises of an embryonal axis to which the cotyledons are attached. The part of the axis above the point of attachment of cotyledons is epicotyl. It bears a bud, the plumule which develops into shoot. The part of the embryonal axis below the point of attachment of cotyledons is hypocotyl. It possesses a meristem at its tip, the radical which develops into primary root.

In monocots the embryo is filamentous type. The cotyledon is terminal and encloses the plumule present at the tip of the embryonal axis whereas the radical is present at the lower end of the embryonal axis.

THE ENDOSPERM

The primary endosperm nucleus divides repeatedly to give rise to a polyploid nutritive tissue, the endosperm, which supply food to the developing embryo. The surplus food is stored in the seeds, e. g., in Pea, Bean and Gram. Such seeds are called endospermic seeds. In some cases the endosperm is completely utilized by developing embryo. Such seeds are known as non-endospermic seeds.

THE SEED

A seed is a ripened ovule protected by seed coat enclosing embryo provided with store food either in endosperms or perisperm.

In dicot (with 2 cotyledons) the embryo consists of a short axis to which the embryonal leaves the cotyledons are attached. The part of axis above the point of attachment of cotyledon is epicotyl while the lower part is hypocotyle. At the upper end of epicotyl a plumule is present. It give rise to embryonal shoot. The lower end of hypocotyle is radical which give rise to primary root.

The Fruit

The ripened ovary is called as fruit. In angiosperms the seeds are enclosed in the fruit.

The seed germinate to sporophyte on germination to a suitable place.

ALTERNATION OF GENERATIONS

Life cycle of an angiosperm comprises of two generations: a spore-producing generation, the sporophyte; and a gamete-producing generation, the gametophyte. Both generations alternate with each other in regular sequence. The reduction division occurs at the time of formation of spores and the diploidy is restored at the time of formation of zygote. The zygote is, therefore first cell of the sporophyte. Another characteristics of angiosperms is formation of endosperm that provides nourishment to the developing embryo.

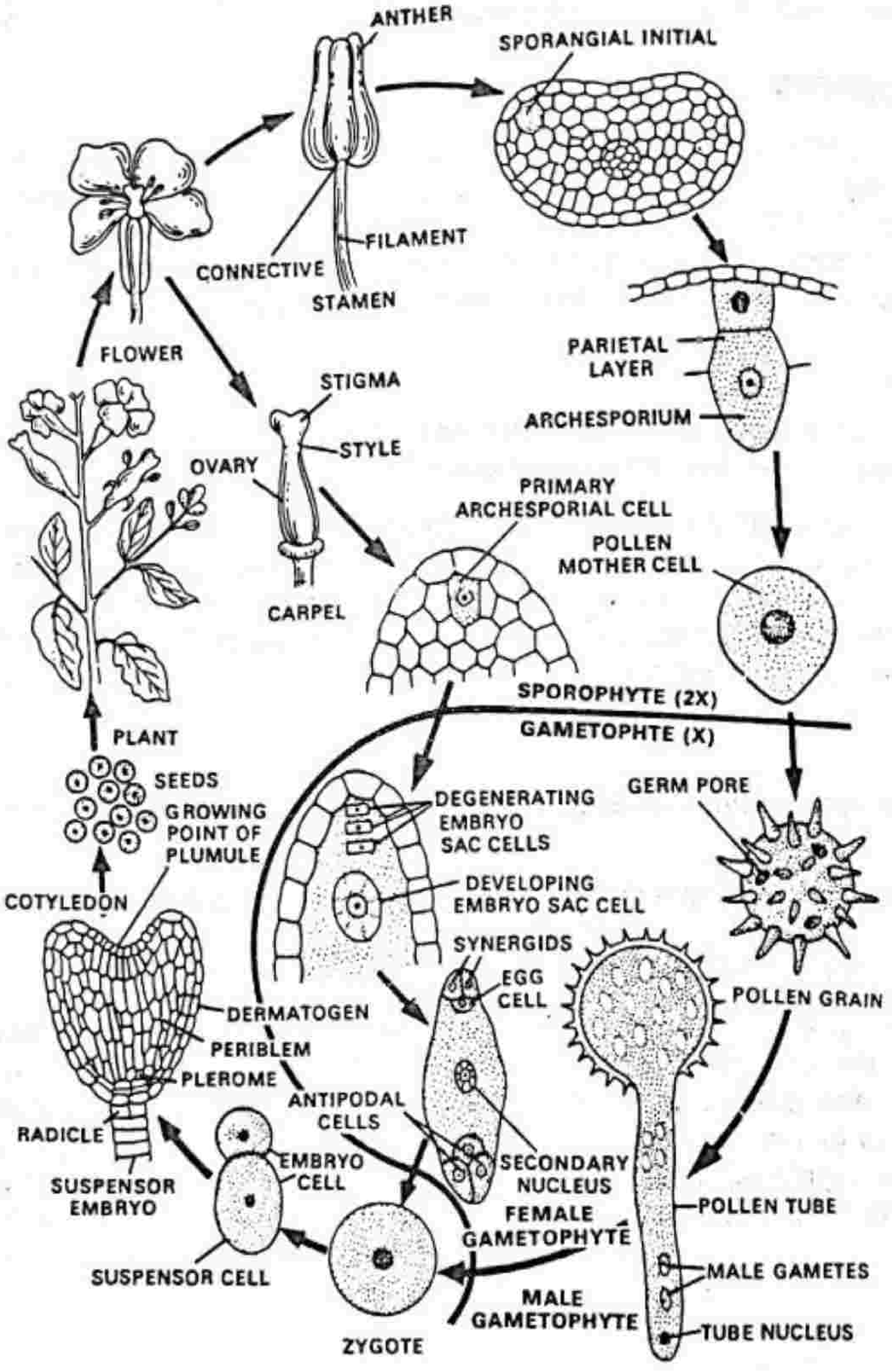


Fig Life Cycle of Angiosperm

SOME IMPORTANT QUESTIONS

A. Short Questions

1. What are angiosperms.
2. Draw structure of a typical flower.
3. What is microspore.
4. What is megasporangium.
5. What is double fertilization.
6. What is endosperms. Give its importance.
7. What is a seed.
8. What is alternations of generation.
9. Draw ovule of angiosperms.
10. Define fruit.

B. Long Questions

1. Describe life cycle of angiosperms.

COMPARISON AMONG GROUPS

BACTERIA & CYANOBACTERIA

Bacteria	Cyanobacteria
1. Bacteria are unicellular structure.	1. Only few forms are unicellular, while majority of them are multicellular and some members forms colonies.
2. They are prokaryotes.	2. They are also prokaryote.
3. Most of the bacteria are colorless.	3. They are bluish green in color.
4. They are usually heterotrophic.	4. They are autotrophic.
5. Photosynthetic pigments are generally absent. But in some members bacterial chlorophyll is present.	5. Photosynthetic pigmen s are present.
6. Cell wall is highly complex and form of murine.	6. Cell wall is usually made up of cellulose.
7. Plasmid is present.	7. Plasmid is absent.
8. They move with the help of flagella.	8. Motile reproductive bodies are entirely absent in this class.
9. Plastids are absent.	9. Plastids are present.
10. Asexual reproduction takes place by binary fission.	10. Asexual reproduction takes place by fragmentation, hormogone etc.
11. Sexual reproduction by conjugation is present.	11. Sexual reproduction is entirely absent.

ALGAE & CYANOBACTERIA

Algae	Cyanobacteria
1. They range in size from unicellular to multicellular structure.	1. Only few forms are unicellular, while majority of them are multicellular and some members forms colonies.
2. They are eukaryotes.	2. They are prokaryote.
3. Cells are usually contain chlorophyll a, b, c & d, carotene and xanthophyll.	3. Cells are blue in color due to the presence of phycocyanine (a blue pigment), chlorophyll, carotene and phycoerytherin.
4. The cells contain mitochondria, endoplasmic reticulum and Golgi bodies.	4. The cells are without any mitochondria,plastids, endoplasmic reticulum and Golgi bodies.
5. A definite nucleus is present.	5. A definite nucleus is absent and nuclear material is present as central body, which lacks nucleus.
6. Photosynthetic pigments are generally present in plastids.	6. Photosynthetic pigments are present. But they are not present in plastids.
7. Reserve food is in the form of starch or starchy substances.. Minute oil drops are also present.	7. Reserve food is in the form of sugars and glycogens. Minute oil drops are also present.
8. They move with the help of flagella.	8. Motile reproductive bodies are entirely absent in this class.
9. They can not withstand high temperature.	9. They can withstand up to 70°C.
10. Asexual reproduction takes place by fragmentation, zoospore, aplanospore etc.	10. Asexual reproduction takes place by fragmentation, hormogone etc.
11. Sexual reproduction by isogamy, anisogamy or by oogamy.	11. Sexual reproduction is entirely absent.

ALGAE & FUNGI

Algae	Fungi
1. Algae are the group of thallophytes that can manufacture their own food.	1. Fungi are achlorophyllus thallophytes and cannot manufacture their own food.
2. They have autotrophic mode of nutrition.	2. They have absorptive mode of nutrition.
3. They range in size from unicellular to multicellular structure.	3. Most of the members are multicellular but some unicellular member like yeast are present.
4. They are unicellular, colonial and filament form.	4. The plant body of fungus consists of mycelium. Some non mycelial fungi like yeast are also present.
5. Cells usually contain chlorophyll a, b, c & d, carotene and xanthophyll.	5. Chlorophyll is absent.
6. Cell wall is made up of cellulose.	6. Chitin is the main constituent of cell wall.
7. Reserve food is in the form of starch.	7. Reserve food is in the form of sugars and glycogens. Minute oil drops are also present.
8. They can withstand high temperature.	8. They cannot withstand high temperature.
9. Asexual reproduction takes place by fragmentation, zoospore, aplanospore etc.	9. Asexual reproduction takes place by fragmentation, spore, conidia formation etc.
10. Sexual reproduction by isogamy, anisogamy or by oogamy.	10. Sexual reproduction is zygospore, ascospore or basidiospore formation.
11. No specialized fruiting bodies are produced.	11. Specialized fruiting bodies like ascocarp or basidiocarp are present.

PTERIDOPHYTES & GYMNOSPERMS

Pteridophytes	Gymnosperms
1. The spore producing plants and they fail to produce seed.	1. They are seed producing plants.
2. Sporophyte and gametophyte generation is independent.	2. No independent gametophytic generation is present and inconspicuous.
3. Adventitious roots are present.	3. Adventitious roots are absent.
4. Stem is usually underground rhizome.	4. The plant body is well differentiated into root stem and leaves.
5. Stele ranging from prtostele to siphonostele.	5. Stele is always siphonostele.
6. Secondary growth is generally absent.	6. Secondary growth is generally present.
7. Sieve tube without companion cell.	7. Sieve tube with albuminous cells are present.
8. Growth of cell is by apical cell.	8. Growth of cell is by apical meristem.
9. Sporophylls may or may not organized to form cone.	9. Sporophylls organized to form cone.
10. Spores are released from sporophyll.	10. Only male spores are released but never megaspores.
11. Male gametes are motile.	11. Male gametes are usually non-motile.
12. Several megaspore mother cells are functional.	12. Generally one megaspore mother cell functional in each sporangium.
13. No seed formation.	13. Seed formation always present.

GYMNOSPERMS & ANGIOSPERMS

Angiosperms	Gymnosperms
1. The seeds are enclosed in fruit.	1. They are naked seeded plants.
2. Root cap developed from calyptron.	2. Root cap developed from dermatogen.
3. Vessel are common in xylem cell.	3. No vessel in xylem.
Reproductive structure form flowers.	4. Reproductive structure form cones.
Flowers have perianth leaves.	5. Cones have no perianth leaves.
Ovule having integument.	6. Ovules are naked.
Sieve tube with companion cell are present.	7. Sieve tube without companion cells are present.
No pollen chamber produce on the ovule.	8. Pollen chamber are produce on the ovule.
Archegonia absent.	9. Archegonia present.
Double fertilization occurs.	10. No double fertilization.
Cotyledons are one or two	11. Cotyledons often more than two..
Fruit present.	12. Fruit absent.

SOME IMPORTANT QUESTIONS

1. Give difference between bacteria and cyanobacteria.
2. Give general characters of cyanobacteria and compare with that of algae.
3. Differentiate between algae and fungi.
4. Differentiate between pteridophytes and gymnosperms.
5. Give comparison between gymnosperms and angiosperms.
6. Compare and contrast between pteridophytes and angiosperms.

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FILL IN THE BLANKS

PLANT DIVERSITY

The Viruses, The Bacteria and Cyanobacteria

FILL IN THE BLANKS:

1. Plant __________ refers to the variety of plants that exist in the world.
2. The prokaryotes appeared about __________ million years ago and comprise a variety of organisms collectively known as bacteria.
3. Eukaryotes appeared first in the late pre-Cambrian period, about __________ million years ago, and probably evolved from prokaryotes.
4. In 1892, D. Iwanowsky prepared an extract from tobacco plants that were suffering from mosaic disease. These disease-causing agents were named filterable __________ .
5. In 1935, __________ demonstrated the structure of plant virus TMV.
6. A plant virus consists of __________ core surrounded by protective protein coat.
7. Viruses range in size from 20 to __________ nm.
8. The virus coats are often built up of identical repeating units called __________ .
9. Bacteriophages and animal viruses contain __________ whereas plant viruses contain RNA usually.
10. Bacteriophages are viruses that infect __________ .
11. These are phages that destroy their host bacterial cell after infection are called __________ .
12. The tobacco mosaic disease is caused by a rod-shaped virus, the __________ (TMV).
13. TMV can withstand a temperature as high as __________ .
14. The development of a "mosaic" or mottled pattern of light and dark green areas in the leaves is due to __________ .
15. TMV can be transmitted from one plant to another by __________ contact.
16. __________ milk is found to be effective in the control of TMV.
17. Bacteria are the smallest organisms having a cellular structure. They are unicellular __________ organisms classified as microorganisms.
18. The study of bacteria is called __________ .
19. One gram of fertile soil is estimated to contain 100 million and 1 cm^3 of fresh milk may contain more than __________ million bacteria.

20. The external components of bacteria include __________ and slime layers, flagella and pilli.

21. Most bacterial capsules are composed of __________ while a few capsules are polypeptides.

22. The capsule provides increased resistance to disease causing bacteria against __________

23. The __________ or sex pilus, are involved in bacterial mating during sexual reproduction.

24. The walls of Gram negative bacteria are thinner as compared to those of __________ bacteria.

25. __________ appear to be associated with DNA during cell division, facilitating the separation of the two daughter molecules of DNA after replication and aiding in the formation of new cross-walls between the daughter cells.

26. In bacteria ribosome consists of two subunits __________ subunit formed of equal amounts of RNA and protein.

27. The bacterial chromosome consists of DNA molecule formed of about __________ base pairs and about 1 mm in length.

28. The bacterial chromosome is primitive and usually referred to as __________.

29. Bacterial cell may have much smaller rings of DNA called __________.

30. There are certain plasmids that are capable of integrating into the bacterial DNA chromosome, they are called __________.

31. In some bacteria, for example *Azotobacter*, whole cell develops into a thick-walled, resistant body called __________

32. The number of bacterial cells double at each division. It is called exponential growth and the time interval is known as __________ time.

33. The usual methods of asexual reproduction are __________ and endospore formation.

34. The sexual reproduction in bacteria is by genetic __________

35. Transfer of cell-free DNA from one cell to another is called __________.

36. Transfer of genes between cells that are in physical contact with one another is called __________.

37. The first evidence of genetic recombination or exchange of hereditary material in bacteria was noted by __________ in 1928.

38. Griffith while working with *Streptococcus pneumoniae*, a bacterium that causes __________ fever.

39. Avery, Macleod and McCarty in 1944 isolated and identified the __________ principle to be DNA.

40. Conjugation involves transfer of DNA between cells in direct contact through __________ tube.

41. The process of conjugation was first demonstrated experimentally by Joshua Lederberg and __________ in 1946. in Escherichia coli.

42. Some bacteria contain an __________ piece of DNA called sex factor or F-factor.

43. The cells without F factor were called female or F⁻ and they are __________ cells.

44. __________ is the transmission of a double-stranded piece of DNA from a donor cell to a recipient cell through a third party usually a bacteriophage.

45. The transduction phenomenon was discovered by __________ and Lederberg in 1952.

46. If all fragments of bacterial DNA have a chance to enter a transducing phage, the process is called __________ transduction.

47. The bacteria can be classified into two nutritional categories on the basis of their nutritional requirements: the __________ and heterotrophic bacteria.

48. The autotrophic bacteria are classified into: photoautotrophs and __________

49. The bacteria in which the energy source is light are called __________.

50. __________ grow in organic media containing hydrogen, carbon dioxide and oxygen and can oxidise hydrogen with the liberation of energy.

51. The region where the soil and roots make contact is called the __________.

52. The nodules are swellings in the roots are composed of cells that contain __________ bacteria.

53. __________ is defined as application of organisms such as bacteria, fungi and algae to the manufacturing and service industries.

54. __________ is manipulation of genes. It is also called recombinant DNA technology.

55. About __________ spp of bacteria are known to cause diseases in plants.

56. __________ proposed a useful classification of bacteria on the basis of form, motility, metabolism, and ecological roles of the bacteria.

57. The members of this cyanobacteria are commonly known as __________

58. A single row of cell in each colony is called as trichome and trichome with mucilage form the __________.

59. In cyanophyceae the cells are blue in color due to the presence of __________ chlorophyll, carotene and phycoerytherin.

60. In cyanophyceae reserve food is in the form of sugars and __________.

61. Special large cells with thick walls called as __________ is present in the filament.

62. When the vegetative cell along with the original cell wall is transformed into a spore is called __________.

63. Sexual reproduction is entirely absent in __________.

64. Blue-green algae especially *Oscillatoria*, *Anabaena* spp grow immensely in storage water and __________ it.

65. In __________ many twisted trichomes aggregate in a gelatinous matrix to form a ball-like globular or ellipsoidal colony which ranges from greenish to bluish-green in colour.

66. The reproduction usually takes place by the following methods in the Nostoc fragmentation, hormogonia, __________., arthrospores.

67. __________ actively participates in nitrogen fixation, therefore increases the fertility of the soil.

68. In __________ cells are cylindrical but broader than long. All the cells are similar in shape except the apical one, which is convex at the top.

69. The jerky pendulum like movement is termed as __________ movement is found in Ocillatoria

THE ALGAE

70. __________ are the chlorophyllus thallophytes that can manufacture their own food and they produce O_2 during photosynthesis.

71. The term thallus is used for a plant body that is not differentiated into __________ and leaves and lacks vascular system.

72. The study of algae is known as __________.

73. The algae exhibit a wide variety of thallus organization. The range of thallus organization is from unicells, __________, filamentous and heterotrichous plant body

74. The colour of algal thallus vary in different divisions because of presence of characteristics chemical compounds called __________.

75. The main algal pigments are __________, carotenoids and phycobilins.

76. __________ are used to classify algae since a particular colour dominates in each division.

77. The motile spores are called as __________.

78. The __________ are non-motile spores.

79. In members of Phaeophyta four non-motile spores are produced per sporangium. These are called __________.

80. If two gametes, similar and size and structure fuse to form the zygote, it is called __________

81. The heterogamous sexual reproduction is of two types, anisogamy and __________.

82. The life cycle during which the haploid phase is long and represents almost all the stages of the life except the diploid phase which is represented by zygote is called __________ cycle.

83. A sexual haploid plant with only zygote diploid is called a __________.

84. The life cycle in which most part of the life cycle is occupied by diploid phase and the haploid phase is represented by gametes only is called __________ cycle.

85. The life cycle in which there is a haploid and a diploid phase which alternate regularly with each other is called __________ life cycle.

86. Algae are divided into several classes on the basis of cell structure, nature of pigments, type of reserve food and __________.

87. The use of algae is very old and is mentioned in the Chinese poetic literature about __________ B.C.

88. Because of their photosynthetic abilities the algae are the __________ producers of the aquatic environments.

89. More than __________ species belonging to green-, brown- and red-algae are used as food for humans.

90. The water contaminated by *Microcystis and Anabaena* causes __________ troubles in human beings.

91. Respiratory disorders have been observed when the water infected by __________ is taken by the humans.

92. The members of __________ are characterized by presence of grass-green chromatophores.

93. The reserve food in chlorophyta is __________ and stored in the plastids.

94. The plant body of __________ is thallus, which consist of single biflagellated cell. It is about 10-30 micron in length.

95. The __________ colony is in the form of a hollow sphere having a definite number of cells arranged at its periphery in a single layer.

96. The number of cells in Volvox vary from __________ .

97. In Volvox several __________ colonies develop within a parent colony.

98. Spirogyra masses of plants are slimy to touch because the filaments are surrounded by pectic sheaths which when come in contact water forms mucilage, therefore it is known as water-silk or __________ .

99. __________ is unbranched with cylindrical cells connected end to end in long green filaments.

100. In spirogyra chloroplasts are __________ shaped, and spirally arranged.

101. In spirogyra the sexual reproduction is primitive type of isogamous sexual reproduction called __________ .

102. In spirogyra the conjugation may be __________ conjugation or lateral conjugation.

103. In spirogyra the zygospore becomes red in colour due to disintegration of chloroplast, accumulation of oil and development of __________ .

104. Chara grows in clear hard water and Mature plant is enriched with $CaCO_3$, therefore, they are called as __________ .

105. In __________ the thallus has long, slender upright branches. The axis is differentiated into node and internodes.

106. The Chara reproduces by vegetative and sexual reproduction. __________ reproduction by spore formation is absent.

107. In Chara star-shaped groups of cells developed from the lower nodes. The cells contain __________ starch.

108. In Chara the male fructification is called as __________ .

109. The female fructification of Chara is called as __________ .

110. In Chara the oogonium is covered by five elongated spirally twisted cells, called as __________ .

111. The members of xanthophyta division are characterized by their yellow-green colour. So. the members of this division are called __________

112. The xanthophycean cell has a definite cell wall chiefly composed of __________ substances.

113. In xanthopyta the chief reserve foods are oil, lipid and __________

114. __________ thallus consists of sparingly branched cylindrical filament. The filament is non-septate multinucleated structure. Septa are produced only during the production of reproductive structure.

115. The terrestrial species of *Vaucheria* produce thin-walled __________ under dry conditions.

116. The members of Bacillariophyta are commonly termed as __________

117. The cell wall in Bacillariophyta is impregnated with __________ which is deposited at the surface of the cell from the silicic acid.

118. In Bacillariophyta the reserve food is oil or __________.

119. The most common method of vegetative reproduction in diatoms is simple by __________.

120. __________ diatoms exhibit bilateral symmetry.

121. __________ diatoms exhibit radial symmetry.

122. The chief reserve food in diatoms is oil. These oils are rich source of vitamin __________.

123. *Pinnularia* consists of __________, which is elongated or elliptical in outline.

124. The *Pinnularia* cell wall is made up of __________ material which is impregnated with silica. So the cell became very hard.

125. The *Pinnularia* __________ consist of two overlapping halves called the valves.

126. The *Pinnularia* flat view is called as valve view while the band view is called as girdle view.

127. __________ is characteristic marking and present on the valve view in *Pinnularia*.

128. In *Pinnularia* there are __________ laminate chloroplast embedded in the cytoplasm.

129. *Pinnularia* chloroplast contain a pigment called as __________ in addition to the normal photosynthetic pigments.

130. The members of Phaeophyta are commonly called brown algae because of dominant carotene and __________.

131. The reserve food in Phaeophyta is __________ and laminarin starch.

132. __________ thallus consists of sparsely or profusely branched uniseriate filaments and exhibits heterotrichous habit. In Ectocarpus asexual reproduction is either by means of biflagellate haploid zoospores produced in one-celled __________ sporangia, or diploid zoospores formed in many-celled plurilocular sporangia.

133. The plurilocular sporangia are stalked or sessile, elongated, cone-like __________ structures.

134. Plurilocular sporangia these also develop from a terminal cell of a short __________ branch.

135. Ectocarpus shows __________ alternation of generations.

136. Laminaria is common __________.

137. The Laminaria plant is diploid and sporophytic. The body of Laminaria varies from __________

138. Rhodophyta is known as __________

139. In Rhodophyta the reserve food is stored as a complex carbohydrate, the __________ starch.

140. Carpospores develop from the __________.

141. Batrachospermum is a __________ water alga found generally in cold running streams of water.

142. The mature thallus of __________ appears as chain of beads.

143. Motile reproductive bodies are entirely __________ in the Batracospermum.

144. The female reproductive organ in Batrachospermum is called as __________

145. The carpogonium along with gonimoblast filament is called as __________.

146. Each filament of gonimoblast filament produce a single nonmotile spore called as __________.

147. Polysiphonia plant body is in the form of erect branched filaments which are attached to the substratum by a disc like basal portion often called as __________ portion.

THE FUNGI

148. Fungi is derived from the latin word __________ which means to flourish.

149. The hyphae are surrounded by cell walls formed of chitin or __________ , or both.

150. The vegetative phase of fungus is a __________ .

151. The mass of hyphae constituting the vegetative body (thallus) of a fungus is called the __________ .

152. The fungus chitin is polysaccharide based on nitrogen containing sugar __________

153. During certain stages of the life history of most fungi, the mycelium becomes organized into loosely or compactly woven tissue. These are called fungal tissues or __________

154. __________ is a loosely woven tissue in which hyphae lie more or less parallel to one another.

155. __________ is a compact, somatic structure much like a cushion on which fungal fruiting bodies are usually formed.

156. The members of Basidiomycotina and some other groups which invade roots of the plants or destroy wood, the hyphae aggregate to form thick longitudinal strands called __________ .

157. The fungi lack __________ , therefore unable to manufacture their own food. They exhibit saprotrophic, parasitic or symbiotic modes of nutrition mostly.

158. In Ectoparasites mycelium remains __________ to the host and absorb food by sending haustoria into the body of the host.

159. __________ is the symbiotic association of fungi with algae. The fungal partner provides shelter and absorb moisture whereas the algal partner synthesizes the food.

160. The hyphae break up into their component cells that behave as spores. These spores are called as __________ .

161. If the cell become enveloped into wall before their seperation from each other they are called as __________

162. __________ involves the fusion of protoplasts to bring the nuclei together.

163. Karyogamy involves the fusion of the __________ .

164. The fungal sex organs are called the __________ .

165. Sexual fusion involves fusion of two naked gametes is called __________ .

166. Some fungi do not go through a true sexual cycle but derive benefits of sexuality through __________ .

167. The parasexual cycles are found in__________.

168. Linnaues was first to recognize and classify fungi as 24th class of his system of classification, the __________

169. The organisms included in Myxomycota division are commonly termed as __________

170. Slime molds differ from true fungi in that they lack __________ and protoplast is surrounded by plasma membrane.

171. Slime molds feeding phase resembles an __________.

172. Plasmodiophoromycetes include __________ slime molds.

173. A unique feature of __________ is a specific type of nuclear division called cruciform division or promitosis.

174. *Plasmodiophora brassica*, a parasite of __________ sp.

175. Life cycle of *Plasmodiophora brassicae* is studied in the tissue culture of *Brassica* __________.

176. The Mastigomycotina, a sub-division of __________.

177. The members of Mastigomycotina are characterized by the presence of one or two flagella in their __________.

178. The members of the Mastigomycotina are characterized by __________ -haploid or diplobiontic life cycles.

179. The Oomycetes comprises of __________ genera with 580 species.

180. Most of the Oomycetes are __________.

181. The species responsible for Damping off is ______________.

182. Mucor appear more readily on damp __________ dung when kept under a bell jar.

183. __________ mycelium consists of numerous, selender, freely branched filaments, the hyphae. The hyphae form a fluffy, white mass called mycelium.

184. Under unfavorable condition the Mucor produced special modified thick walled resting cell called as __________.

185. In Mucor asexual reproduction takes place by formation of non-motile, multinucleate __________. The sporangia arise singly and terminally at the tips of sporangiophores.

186. Mucor display a sexual process which is of __________ type.

187. Ascomycotina fungi is known as __________.

188. The __________ form the largest group of the fungi and contain about 2720 genera and 28650 species.

189. A number of Ascomycotina grow on the dung of various animals called __________

190. Ascomycetes tissues are usually associated with spore bearing structures, the __________.

191. The sexual reproduction in ascomycetes is oogamous and characterized by formation of sexual spores, the __________ .

192. __________ fruiting body is rounded without any opening.

193. Perithecium fruiting body is __________ structure having an opening called ostiole.

194. In perithecium the asci are arranged in a layer forming the __________ on the inner surface of ascocarp.

195. Interspread among the asci may be sterile hair like structure called __________ .

196. __________ fruiting body is cup shaped structure.

197. __________ is characterized by rounded spores and causes vigorous fermentation of sugars.

198. The vegetative cells of common yeast are unicellular, oval or oblong in shape. Some time it may be __________ consisting of chain of cells.

199. The cell wall of yeast is composed of three layers. The outer layer is composed of __________ and some chitin, the middle of glucon and the inner of protein glucon.

200. *Saccharomyces* reproduce asexually by __________ .

201. Sexual reproduction in *Saccharomyces* takes place by the union of two haploid __________ .

202. Penicillia are common and cosmopolitan genus, commonly known as__________ molds.

203. Contamination of Flemming's bacterial culture by *Penicillium notatum* led to the discovery of __________ .

204. In Penicillium the mycelium becomes coloured due to the production of colored __________ .

205. The whole group of metulae and sterigmata on each branch is called __________ in *Penicillium*.

206. The *Penicillium* hyphae, when grown in a medium of sugar solution, divide into small, uninucleate segments which become rounded and separate into thin walled spore-like structures called __________ .

207. The *Phyllactinia* is an obligate endoparasite, causing __________ in different hosts such as shisham.

208. In *Phyllactinia* the young __________ are attached to the surface of the leaves.

209. In __________ the mycelium consists of a network of hyphae.

210. In *Phyllactinia* the cleistothecia are globular, orange to yellow in colour when young, but at maturity becomes __________ .

211. Basidiomycotina are fungi in which the perfect stage spores are __________ .

212. Basidiospores are produced externally on __________ .

213. The number of basidiospores is definite, usually __________ .

214. In Basidiomycetes the septum is characterized by a doughnut-like or barrel-shaped swelling in the center of the septal wall surrounding the central pore. Such a septum is called __________ septum.

215. The mycelium may be primary, secondary or__________ according to phases of development.

216. Clamp Connections is found in many __________ .

217. The sex organs are absent in most of the basidiomycetes and are known only in __________

218. The basidium is the organ in which __________ and meiosis takes place in basidiomycotina.

219. A typical __________ is club-shaped and originates as a terminal cell of a binucleate hypha which becomes separated from the rest of the hypha by a septum over which a clamp connection is generally found.

220. The basidiospore is typically unicellular, uniucleate __________ structure.

221. The wall of the basidiospore is composed of __________ wall layers.

222. The basidiomycetes produce their basidia in highly organized fruiting bodies, the __________ .

223. The mushrooms, shelf-fungi, coral fungi, puffballs, earthstars, stinkhorns and bird-nests fungi, all are __________ .

224. The basidia are formed in definite layers called __________ .

225. Ustilago is a genus of __________ fungi.

226. Ustilago species attack the ovaries of grasses, some times destroying the whole ears and producing a __________ mass of spores.

227. All species of Ustilago genus complete their life cycle on the host and is thus called as __________ parasite.

228. Smut disease is __________ born.

229. The dikaryotic __________ of the fungus are present in the seed.

230. In smut the mass of hyphae consists of short cells, which are __________ .

231. The smut spores are called as __________

232. In *Ustilago tritici*, the __________ germinate to produce the hyphae directly.

233. No basidiospores are produced in __________ .

234. The diplophasic smut mycelium infects the __________ of grasses.

235. In loose smut the __________ are not covered by any membranous structure.

236. In covered smut the spores remain enclosed by a membranous covering of the __________ .

237. The seeds are transferred to hot water having a temperature of __________ for ten minutes to kill the activated mycelium.

238. *Puccinia graminis tritici* is a common on wheat and also parasites on various species of __________ such as oat, barley, rye etc.

239. The fungus completed its life cycle on two different hosts and is called as __________ rust.

240. *Puccinia graminis* causes mostly the stem of wheat causing the __________.

241. In rust the first sign appears early in March in the form of elongated, reddish brown granular postules or __________.

242. The rust sori are called as __________.

243. The__________ are one celled, binucleated, some what globose, slightly thick walled spores.

244. At the end of growing season, the color of uredosori changes from brownish to dark brownish to dark reddish or rusty. This color is due to the production of new spores called as __________ spores.

245. The teleutospores are __________, binucleated, slightly oval and having thick wall.

246. Basidiospores are not able to infect the wheat plant but they infect the alternative host __________.

247. The hyphae of the monokaryotic mycelium form small knots just below the upper epidermis. These cells are then transformed into flask shaped cavities called __________.

248. Agaricus species are commonly called __________ mushrooms.

249. __________ is common, wild, edible and cosmopolitan species.

250. The plant body of the mushroom can be divided into two main parts, the vegetative mycelium and __________.

251. The mycelium producing basidiocarps or mushrooms is referred to as __________ mycelium.

252. The aerial part of the fungus is the __________ of the fungus and is popularly known as mushroom.

253. A mushroom is __________ shaped generally.

254. The upper portion of mushroom is called __________ or cap.

255. The basidiocarp is composed of __________ hyphae which run parallel to each other in stipe region.

256. Agarics produce rings called __________, in the grass.

257. *Agaricus*__________ produces dark green rings in grass.

258. The __________ is the second largest of the fungi and contains 1680 form-genera and over 17000 form-species.

259. Because of absence of perfect stage during their life cycle Deuteromycotina are called fungi __________.

260. The parasexual cycle exhibits __________. It refers to a condition in which genetically different nuclei are associated in the same protoplast.

261. __________ is beaked, pigmented conidia with relatively thin transverse and longitudinal septa.

262. Alternaria reproduces by producing __________ .

263. In *Alternaria* a mature conidium is surrounded by a __________ layered wall.

264. The __________ are an association consisting of a phycobiont and a mycobiont.

265. There are about 18,000 to __________ known species of lichens.

266. About __________ species are involved in lichen formation. The algal components represent about__________ % of the total thallus volume.

267. The majority of fungal components belong to __________ . In few lichens basidiomycetes and deuteromycetes are the fungal partner.

268. The __________ lichen is thin, flat, crust-like and closely appressed to the substratum.

269. __________ thallus is erect or pendent, cylindrical or branched.

270. __________ are small smooth or papilla-like outgrowths present on the upper surface of the thallus.

271. Each isidium consists of algal cells and fungal hyphae surrounded by a __________ layer.

272. __________ are microscopic, bud-like outgrowths of algal cells surrounded by fungal hyphae that are not covered by the cortex.

273. Physcia is a foliose __________ .

274. The plant body of a foliose thallus attached to the substratum through __________ .

275. Physcia reproduces both by vegetative and __________ reproduction.

THE BRYOPHYTA

BRYOPHYTES

276. The term __________ is applied to a group of plants in which the plant body is simple flat thallus, still in the process of developing, resembling to some of thallophyta in vegetative structure, but showing an advance in the method of reproduction.

277. In bryophytes sex organs are __________ and each sex organ is protected by an outer wall of sterile cells surrounding sex cells.

278. Bryophytes exhibit distinct __________ alternation of generations.

279. In bryophytes the principal phase is __________.

280. The sporophyte in bryophytes is simple and comprises of foot, seta and __________.

281. About __________ genera and 24,000 species of bryophytes exist in the universe.

282. Water is required at the time of fertilization for bryophytes therefore they are commonly called __________ of the plant kingdom.

283. The gametophyte is __________ and an independent plant at maturity.

284. In bryophytes the sex organs are __________ and archegonia.

285. In bryophytes the sex organ are __________ and each sex organ is protected by an outer wall of sterile cells surrounding sex cells.

286. Water is essential for __________ in bryophytes.

287. Peat is a brown or dark coloured spongy matter produced as a result of partial decay of dead __________ in the bog.

288. __________ and other mosses are chief components of the peat..

289. The members of the class Hepaticopsida are commonly termed __________.

290. The class Anthocerotopsida includes bryophytes commonly called __________.

291. The members of the class Bryopsida are commonly called __________.

292. *Riccia* belongs to the family __________.

293. *Riccia* is a thallose __________.

294. In *Riccia* Antheridia are found in a linear row on the __________ side of the thallus.

295. The mature sporogonium in *Riccia* is __________ in shape.

296. Riccia sporogonium is enclosed in the enlarged __________ of the archegonium.

297. __________ sporogonium is not differentiated into foot, seta and capsule as in other liverworts.

298. The wall of each mature spore of Riccia is very unevenly thickened and it consists of __________ layers.

299. Porella genus is represented by __________ species.

300. Porella stem is thin, dorsiverantral and branched. The branching is __________ or tripinnate.

301. In Porella the leaves are arranged in three rows, two of large unequally bilobed lateral leaves and one of ventral small leaves called __________ .

302. All species of __________ are strictly dioecious.

303. Porella archegonium can be differentiated into a broad __________ and a venter.

304. Archegonia are found in a group of 15 archegonia remain surrounded by two brackets, a bracteoles and a __________ .

305. The sporophyte in *Porella* is differentiated into a spherical capsule, a seta and a poorly developed __________ .

306. Each spore of Porella is unicellular and its wall is differentiated into __________ layers.

307. The sporophyte of Anthocerotae is long-lived and is differentiated into foot and a very long __________ .

308. Anthoceros comprises of about __________ species.

309. __________ plant is a gametophyte and consists of a small, grassy dark-green, prostrate thallus.

310. The sporophyte phase of Anthoceros is represented by sporogonium in which asexual reproductive units, the __________ are produced.

311. The sporophyte of *Anthoceros* developed on the gametophyte but not depend on the gametophyte and it is __________

312. The central part of the capsule in Anthoceros is __________

313. Bryopsida includes __________ .

314. __________ is a common terrestrial moss which grows in the form of bright green velvety patches in shady and damp places.

315. Funaria genus comprises of __________ species.

316. In Funaria the sporophyte tissue is wounded and produce a protonema. The buds develop on it and each bud grows into a diploid gametophore. This is called as __________ .

317. The gametophore bearing archegonia is called __________ branch.

318. A mature archegonium is __________ shaped which is borne on short stalk.

319. The sporophyte in Funaria is commonly called __________

320. In Funaria the foot is __________ mass of tissue embedded in the apical tissue of the female branch.

321. In Funaria seta consists of a central __________ strand.

322. Funaria capsule is differentiated into three regions, the apophysis, theca and __________.

323. Theca is central part of the capsule and is characterized by presence of sterile central column of tissue called __________

324. The operculum is conical and cap-like terminal region of the __________.

325. The peristome is attached to a ring of thin-walled cells that form rim of the __________.

326. The peristome teeth are hygroscopic and respond to slight changes in __________.

327. *Polytrichum* has __________ species.

328. The sporophyte of *Polytrichum* is massive well differentiated into __________ and capsule.

329. The seta has conducting strands through which __________ is transported.

INTRODUCTION TO VASCULAR PLANTS

330. It is generally agreed that life arose in an aquatic environment and then flourished during more than __________ years.

331. The vascular plants, i. e., the plants having __________ tissues, the xylem and phloem.

332. Vascular plants originated in late __________ period

333. An individual vascular plant usually originates from __________ .

334. The stems of all vascular plants except a few ferns and fossil __________ bear roots.

335. __________ are usually of small size, have single unbranched veins and leaf traces are without leaf gaps.

336. __________ are large in size, their veins are much branched.

337. Megaphylls are considered to be modified __________ .

338. The xylem is water-conducting tissue of the vascular plants that differentiates from __________ .

339. The first formed xylem is called __________ .

340. The later formed xylem is called __________

341. If the maturation of xylem elements occur in a centripetal order, such a xylem is called __________ .

342. Exarch xylem is characteristics of __________ of seed plants.

343. If differentiation of xylem elements starts near the centre of the axis, i. e., centrifugally, the xylem is termed __________ .

344. The xylem consisting of metaxylem only is called __________ .

345. Synchronous xylem is found in the __________ region of angiospermic seedlings.

346. The primary phloem usually differentiates from __________ .

347. The phloem that matures from the procambium after the maturation of stem stops is called __________

348 In pteridophytes and in gymnosperms __________ cells are the conducting cells of the phloem.

349. The xylem and __________ together form the stele

350. The stelar types are used in classification and relationship of __________ plants.

351 When the procambium is in the form of a solid cylinder. the xylem surrounding the phloem, the stele is called __________ .

352 __________ is starch shaped and xylem cylinder has ridges and furrows and the phloem is situated within these furrows.

353. In a __________ , the xylem and phloem form a cylinder around a central pith

354. Ectophloic __________ is stele the phloem is present on the outer surface of the xylem.

355 __________ siphonostele, in which the phloem is both on the outside and inside of the xylem.

356. When the xylem and phloem occur together in discrete bundles, it is called __________ .

357. It has been suggested that siphonosteles developed by progressive replacement of xylem elements by __________ cells in the center of protosteles.

358. The remains of plants and animals, which lived in the remote past, are preserved in the rocks in one form or the other. These are called the __________

359. __________ fossils are formed when the whole plant or part of a plant gets buried under sediments of different types.

360. __________ or Imprints are formed when the sediments around the compressed plant or plant part become hardened.

361. __________ are considered to be the best type of fossils.

362. Petrfication reveal the internal structure of the part which is __________ .

363. During encrustation decaying organisms and air are excluded so that the organisms remain as such even for__________ of years.

364. Calcification process is used by some __________ .

365. Actual Remains __________ fossils are of comparatively young age and do not decompose completely due to low temperature or vacuum.

366. By studying many different sites, the geologists have established a __________ time scale.

367. Geological time scale is grouped into four eras: Precambrian, Paleozoic, Mesozoic and __________ .

368. Each __________ represents a distinct age in the history of earth's life.

369. The beginning of the Paleozoic era is recorded by a great diversity of __________ invertebrates that are absent in the rocks of late Precambrian era.

370. The Palaeozoic and Mesozoic eras are very important from the study point of view of the fossil __________

371. The first land plants are found in upper middle __________ .

372. In the late Palaeozoic forests comprising of __________ , __________ ferns and primitive gymnosperms appeared on earth.

373. The Mesozoic era is important with respect to appearance of __________ plants.

374. The gymnosperms disappeared in the late __________ .

375. Fossil evidence of first photosynthetic organisms comes from a period of the earth's history called the __________ .

376. Cambrian period started, about __________ million years ago, all the evolution of land organisms has occurred.

377. The main fossil record begins in __________ rocks about 600 million years old.

378. Near the end of Cambrian period, by the time of __________ period, the green plants invaded land.

379. About __________ millions years ago, the plants were essentially like those of modern times.

380. Vascular cryptogams are an assemblage of __________ vascular plants that have successfully invaded the land and reproduce by means of spores.

381. __________ have certain characters not found either in bryophytes or in seed plants.

382. The dominant phase in pteridophyte is a __________ .

383. Some primitive pteridophytes were __________ , leafless and free-living sporophytes.

384. The most primitive fossil pteridophyte __________ was leafles.

385. The axis of living genus __________ also bear small appendages without vascular supply.

386. In certain genera of lycopsids small scale-like outgrowth called __________ is present near the adaxial base of each microphyll.

387. The roots of most of the pteridophyte groups are adventitious structures and only in__________ a definite root system is present.

388. The sporophyte of __________ is characterized by the evolution of two general types of conducting tissue, the xylem and phloem.

389. The vascular tissue is present in the form of __________ bundles.

390. The vascular elements develop from a core of or column of meristematic tissue called __________ .

391. The presence of morphologically and physiologically different types of spores is usually referred to as __________ .

392. __________ gametophyte are free-living and not enclosed by the spore wall.

393. __________ gametophytes are present in heterosporous species usually.

394. A sporophyte resulting from apogamy, called __________ sporophyte.

395. The members of Psilopsida are rootless __________ .

396. __________ commonly called whisk fern.

397. The horizontal portion is rhizome. It grows __________ in the soil or humus.

398. In Psilotum aerial branches are green, cylindrical and __________ branched.

399 The sporangia in Psilotum are __________ and are about 2-3 nm in diameter.

400 The group of sporangia is called as __________ .

401 The stele in rhizome of Psilotum is __________ .

402. In Psilotum __________ is absent and xylem occupies centre of the axis and is surrounded by phloem.

403 Psilotum synagium is __________ . stalked structure borne at the apex of a short lateral branch.

404. Trilobed synangium is a fusion product of two or more __________ .

405. Psilotum spore germinates to form a __________ .

406. The Lycopsida division includes both living and extinct genera and has a very long evolutionary history that extends from the __________ till date.

407 The members of the Lycopsida are characterized by presence of __________ leaves.

408. Lycopsida sporangia are associated with fertile leaves, the __________ .

409 Because of their small size, moss-like leaves and aggregation of sporophylls into terminal groups, the members of this division are commonly called __________ or club mosses.

410. In most lycopods the sporophylls are arranged in __________ .

411. Lycopsida embryo is __________ type..

412 Selaginella commonly called a __________ .

413. In many Selaginella species, leafless and colourless branches arise from the prostrate stem near the point of branching are called __________ .

414. Selaginella leaves are small and __________ veined

415 All *Selaginella* species are __________ sporous.

416. In Selaginella the sporangia are borne in the axils of ligulate leaves called __________ .

417 The sporophylls form definite structures called __________ at the ends of shoots.

418 It has been found that embryos may develop by apogamy from __________ initials in some *Selaginella* spp.

419 Production of two types of spore. The microspore in microsporangia and mega spore in megasporangia is called as __________

420. Heterospory is considered a pre-requisite for __________ formation.

421 The __________ stem is jointed and differentiated into distinct nodes and internodes.

422 In sphenopsida __________ canals are present at the inner face of each metaxylem group.

423 __________ is the only living member of the family Equisetaceae.

424. The branching species of Equisetum are called __________ .

425. __________ is a common constituent of cell walls of Equisetum.

426. The genus Equisetum comprises of __________ species which are widely distributed in various habitats.

427 In a transverse section of Equisetum stem outline is wavy due to presence of __________ and grooves.

428. Equisetum stem contain __________ canals. They are present in the cortex just opposite to the groove.

429 Equisetum stele is __________ and the vascular bundles are arranged in a ring around a pith.

430. Equisetum __________ is collateral and consists of xylem and phloem.

431 Equisetum xylem is __________ shaped structure and protoxylem occupies the basal portion while the meta xylem on the tip of the arms.

432. In Equisetum strobili are borne at the tips of non-green __________ branches.

433. Each strobilus consists of a main axis upon which a number of T-shaped peltate appendages called __________ are arranged in whorls.

434. The Pteropsids are broadly termed __________ .

435. There are about __________ living genera and 10,000 species of ferns are present throughout the world.

436. The ferns are well known from the fossil record as far as back as the __________ .

437. The fern leaves are megaphyllous and commonly called a __________ .

438. Asexual reproduction in fern is by __________ formation.

439. *Adiantum* is also called __________ fern.

440. The asexual reproduction in Adiantum is by formation of spores in sporangia which group to form __________ .

441. The sori are groups of sporangia that develop at the margins on the underside of fertile leaves called __________ .

442. The sori are covered with a flap of tissue called the false __________

443. The prothallus of *Adiantum* is __________ shaped structure.

444. Leptosporangiate ferns differ from other ferns in having a __________ with a jacket layer one cell in thickness, a definite number of sores.

445. *Polypodium* genus includes about __________ species.

446. *Polypodium* is a __________ fern.

447. In *Polypodium* sours is spherical and is characterized by absence of __________.

448. Genus *Marselia* is heterosporous and comprises of about __________ species found all over the world.

449. *Marselia* leaves exhibit typical __________ vernation.

450. *Marselia* leaves are compound and each leaf has a long petiole and ________ leaflets.

451. *Marselia* leaflets are arranged in ________ manner.

452. The *Marselia* plant is a ________ sporous sporophyte and characterized by alternation of generations.

453. *Marselia* ________ is bean-shaped structure attached to the petiole through a small stalk called peduncle.

454. The sporocarp ________ the spores until the next wet season.

455. A mature sporocarp is surrounded by a thick and rigid ________ layered wall consisting of the epidermis containing stomata.

GYMNOSPERMS

456 ___________ literally means naked seeds

457 The extinct gymnosperms is the group named seed ferns or ___________

458 The living gymnosperms comprise of about ___________ genera and 725 species

459 The herbaceous and climbing habits are not found in ___________

460 The gymnosperms exhibit well marked secondary growth that results in the formation of secondary xylem and secondary___________

461 The secondary growth is brought about by ___________

462 Distinct ___________ rings are produced during secondary growth

463 The wood produced during secondary growth is commonly termed as ___________ wood.

464 In Pinus and Taxus the cambium is very active therefore pith and cortex are both very reduced resulting in the formation of dense and packed ___________

465 The xylem is without vessels except for in ___________

466 The microspores are produced in ___________

467 Microsporangia develop into ___________ gametophytes.

468 The sporophylls bearing microsporangia are called ___________ whereas those bearing megasporangia or ovules are known as ___________.

469 The sporophylls are arranged spirally along a main axis to form a loose or compact ___________

470 The ovules in gymnosperms are naked, therefore the pollination consists of transfer of partly developed endosporic male gametophyte to the micropylar end of the ___________

471 In living gymnosperms the male gametophytes produce a tubular outgrowth called ___________

472. Pollen tube is usually extension of ___________.

473. The embryo formation is by ___________ division in living gymnosperms, a unique characteristics not found in lower vascular plants and angiosperms.

474 ___________, i.e., the formation of several embryos in a single gametophyte is common in gymnosperms.

475. Resins are plant exudates secreted in specialized ___________ or ducts.

476. David Bierhorst (1971) classified gymnosperms into ___________ classes.

477. The Cycadophyta include both extinct and living gymnosperms with___________ like foliage.

478. Cycadophyta leaves show __________ vernation in bud condition.

479. *Cycas* is cultivated for yield of starch-rich __________ used as food.

480. *Cycas circinalis* is cultivated as __________ for its large attractive palm-like leaves.

481. *Cycas* is a heterosporous __________.

482. *Cycas root* branch dichotomously and form a coral-like mass, therefore called __________ roots.

483. Vascular bundle in *Cycas* are conjoint, open, collateral and __________.

484. *Cycas* reproduces vegetatively by formation of adventitious buds containing reserve food, the __________

485. The male cones of __________ are largest among the male cones in gymnosperms.

486. Each male cone comprises of a central axis to which spirally arranged woody __________ are attached.

487. In Cycas, the megasporophylls are not organized into a __________.

488. *Cycas* __________ consists of loosely arranged megasporophylls which surround the shoot apex like the foliage leaves.

489. Each megasporophyll is __________ leaf-like structure.

490. *Cycas* ovules are naked and about__________ ovules are arranged laterally on the stipe.

491. The transfer of pollen grains from microsporangia to the micropyle of the ovule is called __________.

492. __________ is the largest and most widely distributed Gymnosperms having about 540 species belonging to 50 different genera.

493. The member of __________ group form the major part of world forests.

494. Pine group include some of the largest and the oldest living trees, such as __________, which may attain a height of 300-400 ft with an age of 500-1000 years.

495. Pinus genus consists of about __________ species distributed throughout the world.

496. __________ kinds of branches are found in Pinus.

497. __________ leaves in Pinus are brown in colour and protective in nature.

498. The scale leaves on the dwarf shoots are called __________ which possess a distinct midrib.

499. Pinus needlelike leaves develop singly or in groups at the apices of dwarf shoots called spurs.

500. The spurs grow in the axils of __________ leaves on long shoots.

501. Pinus vascular bundles are conjoint, collateral, open and arranged in a __________.

502 The xylem consists of __________ , xylem parenchyma and is traversed by xylem rays.

503. The phloem comprises of __________ and phloem parenchyma cells.

504. The xylem and phloem of each vascular bundle is separated by a single layered __________

505. The vascular bundles are separated by parenchymatous __________ .

506. The __________ cone of Pinus is the largest among the gymnosperms.

507 Pinus female cone consists of an axis upon which a series of appendages called __________ scales is arranged.

508. A thick wedge-shaped woody scale called __________ scale arises in the axil of each bract scale.

509. In Pinus __________ ovules are borne on the upper surface near the base of the of ovuliferous scale.

510. Pinus ovule is in the form of a small white rounded swelling. It consists of a massive __________ surrounding a small nucellus.

511. The integument is attached to the lower portion of the __________ only.

512. A narrow passage, the __________ is present near the top of the ovule.

513. *Ephedra, Gnetum and Welwitschia* are the three representatives of __________ .

514. The members of Gnetophyta are thought to represent a connecting link between the gymnosperms and __________ .

515. The compound nature of both male and female strobili of Gneotphyta considered similar to the __________ of angiosperms.

516. Ephedra, also commonly known as __________ .

517. The young stem of Ephedra plant is green, ribbed and perform the function of __________ .

518. Ephedra stem is __________ in outline in a transverse section due to presence of ridges and furrows.

519. Ephedra endodermis encloses vascular tissue as a definite __________ is absent.

520 In Ephedra vascular tissue is present in the form of vascular bundles. Each vascular bundle is conjoint, __________ , endarch and open.

521. The vascular cambium is __________ layered.

522. The vascular bundles are arranged in a __________ as in stems of dicot angiosperms.

523. Ephedra xylem of a vascular bundles comprises of tracheids, __________ and xylem parenchyma.

524. Ephedra is the only gymnosperm species possessing __________ , an angiospermic anatomical feature.

525 The phloem consists of sieve cells, phloem parenchyma and __________ cells.

526. Because of superficial resemblance of the reproductive structures of Ephedra to those of angiosperms, these are sometimes referred to as __________ or flowers.

527. Ephedra male cone consists of a main axis upon which a number of pairs of bracts are arranged __________

528. The ovule of Ephedra is unique among the gymnosperms due to presence of __________ integuments.

529. Ephedra ovule integuments surround a parenchymatous__________

530. A Chinese species *Ephedra sinica* is used to prepare __________, a drug used as antihistamine.

THE ANGIOSPERMS

ANGIOSPERMIC PLANT BODY

531 An angiospermic plant consists of vegetative organs the root, stem, branches, leaves and reproductive organs the __________ .

532 The angiospermic plant is __________ and a sporophyte.

533 The innermost layer of sporangium wall is nutritive in nature and called __________

534 The sporogenous cells divide to give rise to microspore mother cells which undergo meiosis to produce __________ of microspores.

535 The microspores germinate to produce __________ gametophyte.

536 The ovary contains one or more rounded or oval bodies, the __________ .

537 The ovules are borne on the ovary wall upon a specialized tissue, the __________ .

538 Each ovule is attached to the placenta through a short stalk, the __________ .

539 The place of attachment of the funicle with the main body of the ovule is __________ .

540. The main body of the ovule consists of sporogenous tissue, the nucellus, surrounded by one or two proetective coverings, the __________ .

541. Nucellus represents megasporangium, therefore the ovule is also termed __________ megasporangium.

542. The gametophyte phase of angiosperms is __________ , much reduced and dependent upon sporophyte.

543. The microspores and megaspopres develop into male and female __________ respectively.

544 The __________ is the first cell of the male gametophyte.

545. The male gametophyte is represented by __________ and pollen tube with two sperm nuclei and a tube nucleus.

546 The __________ is the first cell of the female gametophyte.

547. The female gametophyte is represented by __________ nucleate embryo sac

548 Fertilization in angiosperms is __________ fertilization.

549. The embryo in dicots is octant type and comprises of an embryonal axis to which the __________ are attached.

550. In monocots the embryo is __________ type.

551. The primary endosperm nucleus divides repeatedly to give rise to a polyploid __________ tissue, the endosperm, which supply food to the developing embryo.

552. The surplus food is stored in the __________.

553. A seed is a ripened __________ protected by seed coat enclosing embryo provided with store food.

554. The ripened ovary is called as __________.

555. In angiosperms the __________ are enclosed in the fruit.

ANSWERS

1	Diversity
2	3500
3.	2000
4	Viruses
5	W. Stanley
6.	RNA
7	350
8.	Capsomeres
9	DNA
10.	Bacteria
11.	Virulent phages
12.	Tobacco mosaic virus
13.	93°C
14.	TMV
15.	Direct
16.	Coconut
17.	Prokaryotic
18.	Bacteriology
19.	3000
20.	Capsule
21	Polysaccharides
22.	Antibiotics
23	F pilus
24.	Gram positive
25.	Mesosomes
26.	50S and 30S
27	5 x 10^6
28.	Nucleoid
29.	Plasmids
30.	Episomes
31.	Cyst
32.	Generation
33.	Binary fission
34.	Recombination.
35.	Transformation
36.	Conjugation
37.	Griffith
38.	Pneumonia
39.	Transforming
40.	Conjugation
41.	Edward Tatum
42.	Extra-chromosomal
43.	Recipient
44.	Transduction
45.	Zinder
46.	Generalized
47.	Autotrophic
48.	Chemoautotrophs
49.	Photoautotrophs
50.	Hydrogen Bacteria
51.	Rhizosphere
52.	Nitrogen-fixing
53.	Biotechnology
54.	Genetic engineering
55.	200
56.	Marguilus and Schwartz

57. Blue green algae
58. Filament
59. Phycocyanine
60. Glycogens
61. Heterocyst
62. Akinete
63. Cyanophyta
64. Pollute
65. Nostoc
66. Akinete
67. Anabaena
68. Ocillatoria
69. Oscillatory
70. Algae
71. Root, stem
72. Phycology
73. Colonial
74. Pigments
75. Chlorophylls
76. Algal pigments
77. Zoospore
78. Aplanospores
79. Tetraspores
80. Isogamy.
81. Oogamy
82. Haplontic life
83. Haplont
84. Diplontic life
85. Diplohaplontic
86. Methods of reproduction
87. 600
88. Primary
89. 100
90. Stomach
91. *Gymnodinium brevis*
92. Chlorophyta
93. Starch
94. Chlamydomonas
95. Volvox
96. 500-50,000
97. Daughter
98. Pond-scum
99. *Spirogyra*
100. Ribbon
101. Conjugation
102. Scalariform
103. Haematochrome
104. Stone worts
105. Chara
106. Asexual
107. Amylum
108. Globule
109. Nucule
110. Tube cells
111. Yellow-green algae
112. Pectic
113. Leucosin
114. *Vaucheria*
115. Aplanospores
116. Diatoms
117. Silica
118. Chrysolaminarin
119. Cell division
120. Pennate
121. Centric
122. A and D
Single cell
123. pectic
124. Frustules
125. *Pinnularia*
126. Raphe
127. Two
128. Diatomin
129. Fucoxanthin
130. Mannitol
131 *Ectocarpus,* unilocular

132. Multicellular
133. Lateral
134. Isomorphic
135. Kelp
136. 0.5m to 9m
137. Red algae
138. Floridean
139. Zygote
140. Fresh
141. Batrachospermum
142. Absent
143. Carpogonium.
144. Cystocarp
145. Carpospore
146. Decumbent
147. Fungour
148. Cellulose
149. Thallus
150. Mycelium
151. Glucosamine.
152. plectenchyma
153. Prosenchyma
154. Stroma
155. Rhizomorphs
156. Chlorophyll
157. Outside
158. Lichens
159. Athrospores
160. Chlamadospores.
161. Plasmogamy
162. Nuclei
163. Gametangia
164. Planogametic Copulation
165. Parasexuality
166. Deuteromycotina
167. Cryptogamia.
168. Slime molds
169. Cell wall
170. Amoeba
171. Endoparastic
172. Plasmodiophoromycetes
173. Brassica
174. *napes*
175. Eumycota
176. Zoospores
177. Haplobiontic
178. 74
179. Eucarpic
180. *Phythium debaryanum*
181. Horse
182. Mucor
183. Chlamydospores
184. Sporangiophore.
185. Conjugation
186. Sac fungi
187. Ascomycotina
188. Coprophilous
189. Ascocarps
190. Ascospores
191. Cleistothecium
192. Flasked shaped.
193. Hymenium
194. Paraphyses
195. Apothecium
196. *Saccharomyces*
197. Pseudo-mycelium
198. Mannan-protein
199. Budding
200. Vegetative cells
201. Blue green
202. Penicillin
203. Conidia
204. Pencillus
205. Oidia
206. Powdery mildew
207. Cleistothecia

208. *Phyllactinia*
209. Black
210. Basidiospores
211. Basidia
212. Four
213. Dolipore
214. Tertiary
215. Basidiomycetes
216. Uredinales.
217. Karyogamy
218. Basidium
219. Haploid
220. Five
221. Basidiocarps
222. Basidiocarps
223. Hymenia
224. Smut
225. Black powdery
226. Autoecious
227. Seed
228. Hyphae
229. Binucleated
230. Chlamadospores or teleotospores
231. Promycelium
232. Ustilago
233. Ovaries
234. Spores
235. Grain
236. 54 °C
237. Grasses
238. Heteroecious
239. Black stem rust
240. Sori
241. Uredosori
242. Uredospores
243. Teleuto
244. Two celled
245. *Berberis vulgaris*
246. Pycnidia or spermatia
247. Meadow
248. *Agaricus campestris*
249. Basidiocarp
250. Tertiary
251. Fruiting body
252. Umbrella
253. Pileus
254. Interwoven
255. Fairy rings
256. *Campestris*
257. Deuteromycotina
258. Imperfecti
259. Heterokaryosis
260. *Alternaria*
261. Conidia
262. Two
263. Lichens,
264. 20,000
265. 24, 7
266. Ascomycotina
267. Crustose
268. Fruticose
269. Isidia
270. Cortical
271. Soredia
272. Ascolichen
273. Rhizines
274. Sexual
275. Bryophyta
276. Multicellular
277. Heteromorphic
278. Gametophyte
279. Capsule
280. 960
281. Amphibians
282. Haploid (n)

283. Antheridia
284. Multicellular
285. Fertilization
286. Organic matter
287. Sphagnum
288. Liverworts
289. Hornworts
290. Mosses
291. Ricciaceae
292. Liverwort
293. Dorsal
294. Globular or rounded
295. Venter
296. Riccia
297. Three
298. 184
299. Bipinnate
Aamphigastria
300. *Porella*
301. Neck
302. Perianth
303. Foot
304. Two
305. Capsule
306. 200
307. Anthoceros
308. Spores
309. Semi-independent.
310. Collumella.
311. True mosses
312. Funaria
313. 117
314. Apospory
315. Female
316. Flask
317. Sporogonium
318. Bulbous
319. Conducting
320. Operculum
321. Columella
322. Capsule
323. Capsule
324. Humidity
325. 92
326. Foot, seta
327. Food
328. 3 billion
329. Conducting
330. Silurian
331. Zygote
332. Pteridophytes
333. Microphyll
334. Megaphylls
335. Stems
336. Procambium
337. Protoxylem
338. Metaxylem.
339. Exarach
340. Roots
341. Endarch
342. Synchronous
343. Hypocotyls
344. Procambium
345. Metaphloem
346. Sieve
347. Phloem
348. Vascular
349. Protostele
350. Actinostele
351. Siphonostele
352. Siphonostele
353. Amphiphloic
354. Eustele
355. Parenchyma
356. Fossils.
357. Compressions

358. Impression
359. Petrifecations
360. Petrified
361. Millions
362. Algae
363. Plant
364. Geological
365. Cenozoic
366. Era
367. Fossilized
368. Plants
369. Palaeozoic
370. Ferns, seed
371. Flowering
372. Mesozoic
373. Precambrian
374. 600
375. Cambrian
376. Silurian
377. 70
378. Seedless
379. Pteridophytes
380. Sporophyte
381. Rootless
382. *Rhynia*
383. *Psilotum*
384. Ligule
385. Isoetes
386. Pteridophytes
387. Vascular
388. Vascular cambium
389. Heterospory
390. Exosporic
391. Endosporic
392. Apogamous
393. Sporophytes
394. Psilotum
395. Buried
396. Dichotomously
397. Homosporous
398. Synangium
399. Protostele
400. Pith
401. Trilobed
402. Sporangia
403. Protallus
404. Paleozoic
405. Microphyllous
406. Sporophylls
407. Spike mosses
408. Strobili
409. Quadrant
410. Spike moss
411. Rhizophores
412. Single
413. Hetero
414. Sporophylls
415. Strobili
416. Archegonial
417. Heterospory
418. Seed
419. Sphenopsids
420. Carinal
421. Equisetum
422. Horsetails
423. Silica
424. 25
425. Ridges
426. Vallecular
427. Siphonostele
428. Vascular bundle
429. V
430. Fertile
431. Sporangiophores
432. Ferns
433. 305

434. Devonian
435. Frond
436. Spore
437. Maiden hair
438. Sori
439. Sporophylls
440. Indusium
441. Heart
442. Sporangium
443. 50
444. Homosporous
445. Indusium
446. 70
447. Circinate
448. 4
449. Cruciate
450. Hetero
451. Sporocarp
452. Protect
453. Three
454. Gymnosperms
455. Cycadofilicales
456. 70
457. Gymnosperms
458. Phloem
459. Vascular cambium
460. Annual
461. Secondary
462. Wood
463. Ephedra
464. Microsporangia
465. Male
466. Microsporophylls, Megasporophylls
467. Cone
468. Ovule
469. Pollen tube
470. The inner wall
471. Free nuclear
472. Polyembryony
473. Canals
474. Three
475. Fern
476. Circinate
477. Sago
478. Ornamental
479. Sporophyte
480. Coralloid
481. Endarch
482. Bulbils
483. *Cycas*
484. Microsporophylls
485. Cone
486. Female cone
487. Pinnate
488. 6-8
489. Pollination
490. Coniferales
491. Coniferales
492. Sequoia
493. 90
494. Two
495. Scale
496. Cataphylls
497. Spurs
498. Scale
499. Ring
500. Tracheids
501. Sieve tubes
502. Vascular cambium.
503. Medullary rays
504. Female
505. Bract
506. Ovuliferous
507. Two
508. Integument

509. Nucellus
510. Micropyle
511. Gneotphyta
512. Angiosperms
513. Inflorescence
514. Joint fir
515. Photosynthesis
516. Wavy
517. Pericylce
518. Collateral
519. Single
520. Ring
521. Vessels
522. Vessels
523. Albuminous
524. Inflorescences
525. Decussately
526. Two
527. Nucellus
528. Ephedrine
529. Flowers
530. Diploid
531. Tapetum.
532. Tetrads
533. Male
534. Ovules
535. Placentae
536. Funicle
537. Hilum
538. Integuments
539. Integumented
540. Haploid
541. Gametophytes
542. Microspore
543. Pollen grain
544. Megaspore
545. Eight-
546. Double
547. Cotyledons
548. Filamentous
549. Nutritive
550. Seeds
551. Ovule
552. Fruit
553. Seeds

TRUE FALSE

PLANT DIVERSITY

True or False Statements:

Please select true or false statement by encircling 'T' or 'F' as appropriate

1.	Plants compete with other plants and organisms to survive in an ecosystem.	True / False
2.	Viruses cannot be fitted into a classification of living things because they are not animals.	True / False
3.	Eukaryotes include protoctista, fungi, green plants and animals.	True / False
4.	The genetic material of Monera is circular DNA, occurring naked in the cytoplasm, and normally attached to the cell membrane.	True / False
5.	The kingdom Monera contains all bacteria and cyanobacteria and can be broadly classified into cyanobacteria and eubacteria.	True / False
6.	Cyanobacteria are photosynthetic with photosynthetic pigments held in plasma membranes around the periphery of the cells.	True / False
7.	The sub-kingdom Fungi includes oxygen-producing photosynthetic eukaryotic organisms with a cell structure similar to that of green plants.	True / False
8.	Virus can be defined as non-cellular infectious entities which contain RNA or DNA encased in protein coat and reproduce only in living cell.	True / False
9.	The word VIRUS is derived from English word venom.	True / False
10.	W. Stanley demonstrated the structure of plant virus TMV.	True / False
11.	Viruses do not multiply in cultures designed to support growth of bacteria, i.e., they are non-living outside the host cells.	True / False
12.	Viruses are composed of nucleic acid DNA or RNA core surrounded and protected by a protein coat called capsid.	True / False
13.	Gemini viruses are animal viruses that contain single-stranded DNA as genetic material.	True / False
14.	The viral genome consists of nucleic acids.	True / False

15	Bacteriophages are viruses that infect human.	True / False
16	Like all viruses, the bacteriophages are composed of a nucleic acid core surrounded by a protein coat, the capsid made up of sub-units, the capsomeres.	True / False
17	The tobacco mosaic disease is caused by a rod-shaped virus, the tobacco mosaic virus (TMV).	True / False
18.	The first symptom of TMV disease is a light green coloration between the veins of young leaves.	True / False
19	TMV is transmitted readily through mechanical sap, grafting and dodder.	True / False
20	The sanitation is the main method of disease control.	True / False
21	Milk is found to be effective in the control of TMV.	True / False
22.	Bacteria are the smallest organisms having a cellular structure. They are unicellular prokaryotic organisms classified as microorganisms.	True / False
23	Bacteria are unicellular and very small. Most of them are approximately 0.5 to 1.0 um in diameter and from 0.1 to 1000 um in length.	True / False
24.	Streptococcus pneumoniae causing pneumonia is cocci bacteria.	True / False
25.	Many bacteria secrete sticky substance that form protective layers called slime outside the cell wall.	True / False
26.	The cell wall in bacteria is present beneath the capsule and external to cytoplasmic membrane.	True / False
27.	On the basis of cell wall characteristics the bacteria can be divided into Gram-positive bacteria that can be stained with Gram's stain, and Gram-negative bacteria that do not retain the stain.	True / False
28.	The walls of Gram negative bacteria are thicker as compared to those of Gram positive bacteria.	True / False
29.	In Gram-negative bacteria, the murein layer is coated on the outside with a smooth, soft lipid layer which protect them against antibacterial enzymes.	True / False
30.	The ribosomes are RNA-protein bodies that lie freely in the cytoplasm mostly, and concerned with lipid synthesis.	True / False
31.	In addition to the normal DNA chromosome, the bacterial cell may have much smaller rings of DNA called plasmids.	True / False
32.	Each plasmid consists of few genes and is capable of self-replicating independent of main chromosome.	True / False

33	In case of bacteria the term growth refers to changes in the total population rather than increase in the size or mass of an individual organism.	True / False
34	The exponential growth exhibit an initial period when there appears to be no growth, it is called log phase.	True / False
35	In bacterial recombination the cells do not fuse, and usually only a portion of the DNA from the donor cell is transferred to the recipient cell.	True / False
36.	The first evidence of genetic recombination or exchange of hereditary material in bacteria was noted by Griffith in 1938 during his transforming experiment.	True / False
37.	The bacteria can be classified into two nutritional categories on the basis of their nutritional requirements: the autotrophic and phototrophic bacteria.	True / False
38.	The bacteria that are able to synthesize organic compounds necessary for their survival from simple inorganic substances are called autotrophic bacteria.	True / False
39.	Nitrifying Bacteria are chemo-autotrophs.	True / False
40.	Bacteria are important for their natural roles in the biosphere, for example their role in rhizosphere, nodulation, and nitrogen cycling.	True / False
41.	The division Myxophyta is called cyanobacteria.	True / False
42.	Cyanophyta are commonly known as green algae.	True / False
43.	A few species are endophytes, i. e., live in the cavities of other plants.	True / False
44.	A definite nucleus is absent in Cyanophyceae and nuclear material is present as central body, which lacks nucleus.	True / False
45.	Sexual reproduction is entirely absent in Cyanophyceae.	True / False
46.	A few non-heterocyst species like Oscillatoria princeps and Gloeocapsa sp have also been reported to fix atmospheric nitrogen.	True / False
47.	Some members of blue-green algae such as Chroococcus, Phormidium, e.t.c. form thin mats on soil surface, therefore act as soil binding agents.	True / False
48.	The rice fields are inoculated with Nostoc and Anabaena species. This results in promoting the yield of rice crop.	True / False
49.	Nostoc is common in fresh water ponds. The large colonies found attached as small circular balls.	True / False
50.	In Nostoc twisted trichomes aggregate in a gelatinous matrix to form a ball-like globular colony which ranges from greenish to bluish-green in colour.	True / False

51.	Plastids are absent in Nostoc. The pigments are found in he cytoplasm called as chromatoplasm.	True / False
52.	Cells are blue in color due to the presence of algocyanine, chlorophyll, carotene and phycoerythrin.	True / False
53.	Anabaena is a filamentous green alga.	True / False
54	Anabaena species are characterized by presence of heterocyst and akinetes in their filaments.	True / False
55.	Pseudo vacuoles or gas vacuoles are found in Anabaena cells.	True / False
56.	Heterocysts are sites of carbon fixation.	True / False
57.	Akinetes are non-motile spores formed by transformation of a vegetative cell.	True / False
58.	Reserve food in Nostoc is in the form of sugars and glycogens and cyanophycin.	True / False
59.	The characteristic of Oscillatoria is the slow rhythmic but active movement of the trichome. The movement is jerky pendulum like. This type of movement is termed as oscillatory movement.	True / False
60.	Oscillatoria reproduce asexually. The only method of reproduction is the formation of hormogones.	True / False

THE ALGAE

61.	Algae are the chlorophyllus thallophytes that can manufacture their own food.	True / False
62.	Majority of algal genera are non aquatic.	True / False
63.	The colour of algal thallus vary in different divisions because of presence of characteristics chemical compounds called pigments.	True / False
64.	Four different kinds of chlorophylls, a, b, c, d and e, are found in algae.	True / False
65.	The motile spores are called as azoospore.	True / False
66.	In some algae the protoplast divides to form spherical units which secrete new walls. These are called endospores.	True / False
67.	In members of Phaeophyta four non-motile spores are produced per sporangium. These are called monospores.	True / False
68.	Colour of members of the class Chlorophyceae is green or grass green due to presence of chlorophyll a and b, xanthophylls and carotenoid.	True / False
69.	Bacillariophyceae are commonly known as diatoms.	True / False
70.	The division Chlorophyta includes a single class Chlorophyceae.	True / False
71.	Chlamydomonas is marine water free swimming alga.	True / False
72.	In Chlamydomonas a bean shaped chloroplast is present in the cell.	True / False
73.	The main function of the eye spot in Chalaymadomonas to detect the direction and intensity of the light.	True / False
74.	The Volvox is a green, flagellated, colonial alga found in both temporary and permanent water ponds, pools and ditches.	True / False
75.	The Volvox colony is in the form of a fluid filled sphere having a definite number of cells .	True / False
76.	The number of cells in Volvox vary from 50-50,00.	True / False
77.	The structure of each cell of Volvox is resembled with the Chlamydomonas.	True / False

78.	The spirogyra grows abundantly in spring.	True / False
79.	Spirogyra is branched with cylindrical cells connected end to end in long green filaments.	True / False
80.	In Spirogyra sexual reproduction is primitive type of isogamous sexual reproduction called conjugation.	True / False
81.	Scalariform Conjugation occurs between opposite cells of the neighboring filaments.	True / False
82.	In lateral conjugation, gametes are formed in two filament.	True / False
83.	Charophyta plant body is macroscopic and resembles those of Arthrophyta.	True / False
84.	The reproduction in Charophyta is vegetative, asexual and sexual.	True / False
85.	Amylum stars are densely filled with glucose.	True / False
86.	The asexual reproduction by the formation of spores is absent in Chara.	True / False
87.	Chara grows submerged in fresh water and upon muddy or sandy bottoms of pools and ponds, or in limestone streams.	True / False
88.	Spirogyra are called as stone worts.	True / False
89.	In Chara asexual reproduction takes place by Amylum Stars and Bulbils.	True / False
90.	The sexual reproduction in Chara is an advanced type of oogamous sexual reproduction.	True / False
91.	In Chara gametes are produced in antheridia and oogonia that are enveloped in multicellular sheaths formed of cells derived from the cells present below the sex organs.	True / False
92.	The male fructification is called as globule.	True / False
93.	In Chara each antherozoid is an elongated some what coiled structure. It bears two flagella.	True / False
94.	At the top of the oogonium of Chara is a crown of small five cells called the corona.	True / False
95.	The members of Xanthophyta division are characterized by their golden yellow-green colour.	True / False
96.	The xanthophycean cell has a definite cell wall chiefly composed of pectic substances either pectose or pectic acid.	True / False

97.	In Xanthophyta the asexual reproduction may be by zoospores, aplanospores and akinetes.	True / False
98.	The diatome comprises of a single class: Bacillariophyceae including about 200 genera and 16,000 species.	True / False
99	Each frustule in diatoms is composed of three overlapping halves, the valves, one being larger and overlapping the other.	True / False
100.	The cell wall in diatoms is impregnated with silica which is deposited at the surface of the cell from the silicic acid present in the environment surrounding the cell.	True / False
101.	Pinnularia is very common in fresh water ponds, ditches, on the surface of mud in the drying ponds and on the moist soils.	True / False
102.	Pinnularia plant consists of single cell, which is 2-3 times as longer as broad.	True / False
103.	The central region of the diatom wall is traversed by a cleft or groove called the raphe.	True / False
104.	There are two laminate chloroplast embedded in Pinnularia cytoplasm.	True / False
105.	Pinnularia contain a pigment called as diatomin in addition to the normal photosynthetic pigments.	True / False
106.	The members of Phaeophyta are commonly called brown algae because of dominant carotene and fucoxanthin.	True / False
107.	Ectocarpus thallus consists of sparsely or profusely branched uniseriate filaments and exhibits heterotrichous habit. There are two types of filaments, the prostrate and erect filament.	True / False
108.	Ectocarpus reproduces asexually by azoospores and sexually by isogamy or anisogamy.	True / False
109.	Ectocarpus shows isomorphic alternation of generations.	True / False
110.	The sporophyte is diploid and bears two types of sporangia, the plurilocular sporangia in which zoospores are formed as a result of mitosis, and the unilocular sporangia in which the zoospores are produced meiotically.	True / False
111.	The Laminaria plant is haploid and sporophytic.	True / False
112.	In Laminaria there is distinct alternation of generation.	True / False
113.	The red algae like brown algae are predominantly marine, however some species like Batrachospermum are freshwater and are found in streams, lakes and streams.	True / False

114.	The reserve food is stored as a complex carbohydrate, the floridean starch in Red Algae.	True / False
115.	The red algae produce one or more kinds of motile asexual spores.	True / False
116.	Monospores are develop singly in Batrachospermum.	True / False
117.	Batrachospermum is a fresh-water alga found generally in cold running streams of water.	True / False
118.	Batrachospermum thallus is in the form of a spawn-like mass covered with soft and thick mucilage, therefore is commonly known as frog spawn.	**True / False**
119.	Motile reproductive bodies are entirely absent in the Batrachospermum.	True / False
120.	Polysiphonia plant body is in the form of erect branched filaments which are attached to the substratum by a disc like basal portion often called as decumbent portion.	True / False
121.	There is heteromorphic alternations of generation of gametophytic and sporophytic generations in Polysiphonia.	**True / False**

THE FUNGI

GENERAL CHARACTERS

122.	Pier Antonio Michell, an Italian botanists, first published his research on fungi in 1729 entitled Nova Plantarum Genera.	True / False
123.	The fungi are eukaryotic, achlorophyllous organisms consisting of filamentous, septate or aseptate somatic structures called hyphae.	True / False
124.	About 500 genera and more than 50,00 species of the fungi are known today.	True / False
125.	The mass of hyphae constituting the vegetative body (thallus) of a fungus is called the mycelium.	True / False
126.	The fungal cells are typically eukaryotic and having chloroplasts.	True / False
127.	The formula of fungus chitin is (C22 H54 N4 O21)n.	True / False
128.	Prosenchyma is a loosely woven tissue in which hyphae lie more or less parallel to one another.	True / False
129.	Stroma is a compact, reproductive structure much like a cushion on which fungal fruiting bodies are usually formed.	True / False
130.	The members of Basidiomycotina and some other groups which invade roots of the plants or destroy wood, the hyphae aggregate to form thick longitudinal strands called rhizomorphs.	True / False
131.	Appressoria are found in disease-causing fungi.	True / False
132.	Haustoria are found in non parasitic fungi such as Albugo	True / False
133.	The saprotrophic fungi absorb food from the substratum by sending ordinary hyphae or by development of rhizoids into the substratum.	True / False
134.	The common examples of parasitic fungi are Mucor, Rhizopus, Penicillium, Agaricus, etc.	True / False
135.	The hyphae break up into their component cells that behave as spores. These spores are called as arthrospores.	True / False
136.	When the spores are produced inside the sporangium then it is called as spores.	True / False
137.	If the spore like structure produced externally in the form of chain then it is called as conidia.	True / False

138.	Linnaues was first to recognize and classify fungi as 24th class of his system of classification, the Cryptogamia.	True / False
139.	The fungi was placed in Thallophyta because zygote develop into a multicellular embryo while it is still attached to the female reproductive organ.	True / False
140.	The fungi are evolved from the bacteria.	True / False
141.	Ainsworth's system is considered to be most ideal scheme of classification of fungi and it reflects natural relationship among the members of the groups.	True / False
142.	The organisms included in myxomycota are commonly termed as slime mold.	True / False
143.	Plasmodiophora brassicae is an obligate endoparasite in the roots of members of family Poaceae.	True / False
144.	The somatic phase of slime mold is a plasmodium.	True / False
145.	The Mastigomycotina, a division of Eumycota .	True / False
146.	The Oomycetes comprises of 74 genera with 580 species.	True / False
147.	The complex Oomycetes are parasites of terrestrial plants and pass their whole life in the host.	True / False
148.	Phythium live as parasite and causing a disease known as Damping Off on various crops like tobacco, mustard etc.	True / False
149.	Phythium debaryanum sexual reproduction takes place by the formation of kidney shaped zoospores bearing two flagella.	True / False
150.	Mucor mycelium consists of numerous, selender, freely branched filaments, the hyphae. The hyphae form a fluffy, white mass called mycelium.	True / False
151.	Mucor under unfavorable condition the fungus produced special modified thick walled resting cell called as uredospores.	True / False
152.	Mucor is columellate fungi.	True / False
153.	The Ascomycotina include a wide range of diverse organisms such as yeast, black molds, blue molds, ringworms, powdery mildews, black mildews, cup fungi, morels and truffles.	True / False
154.	The asexual stage is represented by conidia or spores and is often termed as perfect stage.	True / False
155.	The sexual reproduction in ascomycetes is oogamous and characterized by formation of sexual spores, the ascospores.	True / False

156.	Ascospores are produced in specialized structures, the asci contained in special fruiting bodies, the ascocarps.	True / False
157.	The ascus is an globose cylindrical, structure that represents a single cell in which ascospores are produced.	True / False
158.	Each ascogenous hypha produces a branch from one or more of its dikaryotic cells, the tip of which bends to form a hook or crozier, containing two compatible nuclei.	True / False
159.	Saccharomyces is characterized by rounded spores and causes vigorous fermentation of sugars.	True / False
160.	Yeast contained about 51 species, among them Saccharomyces cerevisiae is most common.	True / False
161.	Yeast are the unicellular member of Ascomycetes.	True / False
162.	Saccharomyces reproduce asexually by budding.	True / False
163.	Schizosaccharomyces octosporus, commonly called fission yeast exhibits multiplication by simple fission.	True / False
164.	Penicillium notatum mycelium is well developed and is profusely branched. It is composed of colourless, slender, tubular, branched, and septate hyphae.	True / False
165.	Penicillium mycelium becomes coloured due to the production of colored spores.	True / False
166.	In Penicillium whole group of metulae and sterigmata on each branch is called pencillus.	True / False
167.	The Penicillium hyphae, when grown in a medium of sugar solution, divide into small, uninucleate segments which become rounded and separate into thin walled spore-like structures called basidia.	True / False
168.	The peridium is the wall of the ascocarp.	True / False
169.	The ascocarp is without an opening is termed as a cleistothecium.	True / False
170.	The Phyllactinia is an obligate endoparasite, causing powdery mildew in different hosts such as shisham.	True / False
171.	Phyllactinia mycelium consists of a naked hyphae.	True / False
172.	The Basidiomycotina are fungi in which the perfect stage spores are basidiospores and these are produced externally on basidia.	True / False
173.	The number of basidiospores is definite, usually eight.	True / False
174.	The hyphae composing the mycelia in basidiomycetes are septate and the septa are characterized by presence of a pore that allows cytoplasmic continuity. The septum is	True / False

	characterized by a doughnut-like or barrel-shaped swelling in the center of the septal wall surrounding the central pore. Such a septum is called dolipore septum.	
175.	The primary mycelium gives rise to secondary mycelium. The development of secondary mycelium usually involves an interaction between two compatible homokaryotic mycelia. This phenomenon is called dikaryotization.	True / False
176.	The secondary mycelium forms complex tissues to produce sporophores or basidiocarps. This organized, specialized tissue is called primary mycelium.	True / False
177.	Clamp Connections is a mechanism found in many ascomycetes.	True / False
178.	The basidium is the organ in which karyogamy and meiosis takes place in basidiomycotina, as a result of which generally four basidiopsores are produced on the surface of the basidium.	True / False
179.	A typical basidium is club-shaped and originates as a terminal cell of a binucleate hypha which becomes separated from the rest of the hypha by a septum over which a clamp connection is generally found.	True / False
180.	The two nuclei within the basidium fuse and the fusion nucleus undergoes meiosis to produce five haploid nuclei.	True / False
181.	The basidiospore is typically unicellular, uniucleate diploid structure.	True / False
182.	The wall of the basidiospore is composed of five wall layers and have germ pores in them through which the basidiospore germinate.	True / False
183.	The basidiomycetes produce their basidia in highly organized fruiting bodies, the basidiocarps.	True / False
184.	The mushrooms, shelf-fungi, coral fungi, puffballs, earthstars, stinkhorns and bird-nests fungi, all are ascocarps.	True / False
185.	The basidia are formed in definite layers called hymenia.	True / False
186.	Ustilago is a genus of smut fungi.	True / False
187.	Ustilago is a facultative parasite and cause a disease called as rust.	True / False
188.	The genus ustilago attack ovaries of grasses, some times destroying the whole ears and producing a black powdery mass of spores.	True / False
189.	In smut flowers are replaced by black powdery mass of spores.	True / False
190.	Smut spores are called as basidiospore.	True / False

191.	The smut disease is water born.	True / False
192.	The dikaryotic hyphae of Ustilago are present in the seed.	True / False
193.	The mass of smut hyphae consists of short cells, which are binucleated.	True / False
194.	Smut spore is unicellular and binucleate.	True / False
195.	The optimum temperature for germination of smut spore ranges from 30-40°C.	True / False
196.	In Ustilago tritici, the promycelium germinate to produce the hyphae directly. Which is then conjugated to produce the dikaryotic hyphae. No basidiospores are produced.	True / False
197.	As the smut disease is seed borne, a careful selection of seeds from a healthier crop will help in control of the disease.	True / False
198.	A temperature as high as 36 °C may damage the embryo.	True / False
199.	Raising and sowing resistant varieties of wheat is one of the simplest and effective methods of control of the disease.	True / False
200.	Puccinia graminis is a common on wheat and also parasites on various species of grasses such as oat, barley, rye etc.	True / False
201.	The rust fungus completed its life cycle on two different hosts and is called as monoecious rust.	True / False
202.	Two stages, are present in the typical life cycle of puccinia.	True / False
203.	Uridinial and Telial stages is present on wheat plant while the Pycenial and Asial stages are present on the Barberry plant.	True / False
204.	Puccinia graminis causes mostly the stem of wheat causing the white stem rust.	True / False
205.	The first sign of rust appears early in March in the form of elongated, reddish brown granular postules or sori. These sori are called as uredosori.	True / False
206.	The uredospores are 2 celled, binucleated.	True / False
207.	The tleutospores are two celled, binucleated, slightly oval and having thick wall.	True / False
208.	Each basidiospore is one celled and binucleated.	True / False
209.	Each aceospore is unicellular, binucleated and generally rounded in form.	True / False
210.	Agaricus species are commonly called meadow mushrooms.	True / False

211.	The Agaricus genus contains some of the fine edible mushrooms including Agaricus campestris and Agaricus bisporus.	True / False
212.	Primary mycelium is monokaryotic, short-lived and develops from germination of a basidiospore.	True / False
213.	The mycelium producing basidiocarps or mushrooms is sometimes referred to as primary mycelium.	True / False
214.	The aerial part of the Agaricus fungus is the fruiting body of the fungus and is popularly known as mushroom.	True / False
215.	A mushroom is bean shaped generally.	True / False
216.	The basidiocarp is composed of interwoven hyphae which run parallel to each other in stipe region and are compactly arranged to form a pseudoparenchymatous tissue in the pileus region.	True / False
217.	Some of the hyphae of pileus develop into lamellae or gills.	True / False
218.	Because of absence of asexual stage during their life cycle Deuteromycotina are called fungi imperfecti.	True / False
219.	The deuteromycetes are characterized by the presence of a specific cycle, called parasexual cycle, in which plasmogamy, karyogamy, and haplodization take place, but not at a specified time or specific points in the life cycle of an organism.	True / False
220.	The parasexual cycle exhibits heterokaryosis. It refers to a condition in which genetically different nuclei are associated in the same protoplast. It is the first step during parasexual cycle.	True / False
221.	Alternaria occur as saprobes on dead and decaying organic materials, on seeds.	True / False
222.	The characteristics feature of Alternaria genus is production of obclavate or beaked, pigmented conidia with relatively thin transverse and longitudinal septa.	True / False
223.	Alternaria reproduces by producing spores.	True / False
224.	There are about 18,000-20,000 known species of lichens.	True / False
225.	Physcia is a foliose basidiolichen	True / False

BRYOPHYTES

226.	Bryophyta sex organs are multicellular and each sex organ is protected by an outer wall of sterile cells surrounding sex cells.	True / False
227.	Bryophyta exhibit isomorphic alternation of generations.	True / False
228.	The principal phase in Bryophyte is gametophyte.	True / False
229.	The sporophyte is simple and comprises of foot, seta and capsule.	True / False
230.	Sporophyte in Bryophyte is independent, but remains attached to the gametophyte throughout its life.	True / False
231.	About 960 genera and 24,000 species of bryophytes exist in the universe.	True / False
232.	Water is not essential for fertilization in bryophytes.	True / False
233.	The zygote in bryophyte is retained within the venter and develops into an embryo without delay.	True / False
234.	The zygote undergoes repeated divisions to form an undifferentiated, multicellular structure, the gametophyte plant.	True / False
235.	A mature sporogonium consists of a basal swollen foot, a stalk or seta, and a spore-producing structure, the capsule.	True / False
236.	The capsule of bryophyte comprises of sporogenous cells surrounded by a layers of sterile cells.	True / False
237.	The division Hepatophyta or liverworts, contains over 500 genera.	True / False
238.	Hepatopsida 40 comprises of about 4 genera and 420 species.	True / False
239.	Riccia is a thallose liverwort in which the vegetative plant, which is a gametophyte, generally forms rosettes due to the crowded growth of the thallus.	True / False
240.	Riccia plants, like other liverworts, multiply vegetatively by the decay or death of the older parts.	True / False
241.	The mature sporogonium in Riccia is globular or rounded in shape and is enclosed in the enlarged venter of the archegonium.	True / False
242.	Riccia sporogonium is differentiated into foot, seta and capsule as in other liverworts.	True / False

INTRODUCTION TO VASCULAR PLANTS

271.	An individual vascular plant usually originates from zygote.	True / False
272.	The stems of all vascular plants except a few ferns and pteridophytes bear roots.	True / False
273.	Roots differ externally from stems in not bearing leaves and not differentiated into nodes and internodes.	True / False
274.	The xylem consisting of metaxylem only is called synchronous.	True / False
275.	The xylem and phloem together form the stele.	True / False
276.	Almost all rocts are protostelic.	True / False
277.	When the xylem and phloem occur together in discrete bundles, it is called eustele.	True / False
278.	The remains of plants and animals, which lived in the remote past, are preserved in the rocks in one form or the other. These are called the fossils.	True / False
279.	Imperation are considered to be the best type of fossils.	True / False
280.	Chemical materials like amino acids and hydrocarbons may be obtained in a natural state are a type of fossils.	True / False
281.	By studying many different plants, the geologists have established a geological time scale.	True / False
282.	Time scale that reflects a consistent sequence of historical periods. It is grouped into four eras: Precambrian, Paleozoic, Mesozoic and Cenozoic.	True / False
283.	Each era represents a distinct age in the history of animal life.	True / False
284.	The Palaeozoic and Mesozoic eras are very important from the study point of view of the fossil plants.	True / False
285.	The first land plants are found in upper middle Palaeozoic.	True / False
286.	In the late Palaeozoic forests comprising of ferns, seed ferns and primitive gymnosperms appeared on earth.	True / False
287.	Since the Cambrian period started, about 800 million years ago, all the evolution of land organisms has occurred.	True / False
288.	In 1954, the first fossilized remains of organisms was reported in a very hard rock called chert of Precambrian age, about 1.6 billion years old.	True / False
289.	The main fossil record begins in Cambrian rocks about 600 million years old.	True / False
290.	Land plants were very common in the Silurian, or even early in the Devonian.	True / False

PTERIDOPHYTES

291.	On the basis of vegetative structure of the sporophyte, the manner sporangia are borne and the structure of the sporangia, the pteridophytes can commonly be differentiated as psilophytes, lycopods, horsetails and ferns	True / False
292	Psilotum and Tmesipteris are two living pteridophytes which have retained old primitive characteristics.	True / False
293.	The modern survivors of psilophytes Psilotum and Tmesipteris are also have root.	True / False
294.	In Dichotomous Branching root or shoot apex divides into two sister apices, each developing into a branch of equal size, for example in Psilotum.	True / False
295.	Monopodial branches develop laterally some distance behind the main shoot apex from axillary buds.	True / False
296.	The most primitive fossil pteridophyte Rhynia was leafles.	True / False
297.	Psilophyta includes all extinct genera.	True / False
298.	Psilotum, commonly called fern.	True / False
299.	Psilotum rhizome bears aerial branches. The aerial branches are green, cylindrical and dichotomously branched.	True / False
300.	Psilotum sporangia are homosporous and are about 10 nm in diameter.	True / False
301.	Sporangium are found in groups of three on short stalk in the axial of small bifid leaves. This group of sporangia is called as synangium.	True / False
302.	In Psilotum the xylem is actinostelic and radial in out line having six rays	True / False
303.	Between the endodermis and the xylem is the pith.	True / False
304.	Psilotum synagium is trilobed, stalked structure borne at the apex of a short lateral branch.	True / False
305.	The development of the synagium is protoporangiate.	True / False
306.	Psilotum gametophytes are small, cylindrical and dichotomously branched usually.	True / False
307.	The entire surface of the Psilotum thallus is covered with roots.	True / False

308.	Lycopsida includes both living and extinct genera and has a very long evolutionary history that extends from the Paleozoic till date	True / False
309.	The Microphyllophyta stem may be dichotomously branched or modified into monopodium.	True / False
310.	In most lycopods the sporophylls are arranged in strobili.	True / False
311.	Selaginella commonly called a club moss or spike moss.	True / False
312.	In Selaginella kraussiana aerial roots with well developed caps and cutinized epidermal cells exist. These enter the soil.	True / False
313.	Some Selaginella species reproduce vegetatively by development of adventitious branches which separate from the parent plant and develop into new gametophyte.	True / False
314.	All Selaginella species are heterosporous.	True / False
315.	In Selaginella the spores are produced in separate sporangia known as microsporangia and megasporangia.	True / False
316.	The sporangia are borne in the axils of ligulate leaves called sporophylls.	True / False
317.	The sporophylls form indefinite structures called strobili at the ends of shoots.	True / False
318.	The sporophylls are almost like vegetative leaves and arranged spirally upon the axis of the strobilus.	True / False
319.	Both micro- and megasporangium consist of a two-layered sporangium wall surrounding tapetum and sporogenous tissue.	True / False
320.	The tapetum develops from outermost layer of sporangium wall.	True / False
321.	Parthenogenesis is more profound in Selaginella.	True / False
322.	Production of two types of spore. The microspore in microsporangia and mega spore in megasporangia is called as apospory.	True / False
323.	Heterospory is considered a pre-requisite for seed formation.	True / False
324.	All seed plants are heterosporous.	True / False
325.	The megasporangium does not retained on the sporophyte and the female gametophyte is retained within the megasporangium.	True / False
326.	Selaginella is the first living vascular cryptogam to exhibit heterospory.	True / False

327.	In Selaginella rupestris, the megaspore is retained on the sporophyte and fertilization and development of embryo takes place within it.	True / False
328.	Sphenopsida division includes a group of vascular cryptogams known from Devonian strata.	True / False
329.	The plants were less during the Paleozoic, but only one genus Equisetum has survived.	True / False
330.	The members of sphenopsida are commonly called horsetails.	True / False
331.	In primitive sphenopsids the sporangiophore is cylindrical, once or twice dichotomously branched, and each dichotomy ultimately recurve and terminate in a single sporangium.	True / False
332.	In Equisetum, each sporangia is peltate and a whorl of rudimentary bracts is present below the sporangiophore forming annulus.	True / False
333.	The sporangia are borne on the undersurface of the head.	True / False
334.	Most sphenopsids are heterosporous.	True / False
335.	The gametophytes of Equisetales are long-lived and cushion-like first but become lobed and irregular in shape later due to more active growth at one side. The sex organs lie between the lobes.	True / False
336.	In Equisetum the zygote germinate to produce quadrant type of embryo.	True / False
337.	Equisetum is the only living member of the family Equisetaceae	True / False
338.	Equisetum has perennial underground stem, which grows horizontally. It often penetrate deeply into the soil.	True / False
339.	Vallecular canals are present in the cortex just opposite to the groove.	True / False
340.	Equisetum stele is siphonostele and the vascular bundles are arranged in a ring around a pith.	True / False
341.	In the mature vascular bundle a cavity called as vallecular canal is formed by the disintegration of xylem tissues.	True / False
342.	In Equisetum the presence of silica in the stem gives a rough and abrasive touch and bundles of stems are used to clean utensils and for polishing wood.	True / False
343.	The plant of Equisetum arvense is used as a diuretic.	True / False
344.	The pteropsids are broadly termed ferns.	True / False
345.	Ferns are about 305 living genera and 10,000 species present throughout the world.	True / False

346	The ferns are well known from the fossil record as far as back as the Devonian.	True / False
347	The true ferns are found in Permian and the present day survivors evolved during Triassic and recent.	True / False
348.	The leaves are megaphyllous and commonly called a frond.	True / False
349.	Adiantum spp are common in plains and hilly tracts of Pakistan.	True / False
350.	Adiantum is also called maiden hair fern.	True / False
351.	Leptosporangiate ferns differ from other ferns in having a sporangium with a jacket layer one cell in thickness, a definite number of sores within a sporangium, a development of sporangium from a single initial cell, and a differentiation of the tapetum from a single internal cell of a developing sporangium.	True / False
352.	Polypodium genus includes about 100 species of leaf-losing.	True / False
353.	Polypodium plant body consists of creeping, slender branched rhizome that grows to 2 mm in diameter.	True / False
354.	Genus Marselia is monosporous and comprises of about 70 species found all over the world.	True / False
355.	In Marselia the stele in root is monarch or diarch protostele	True / False
356.	Marselia minuta and M. hirsuta reproduce vegetatively by formation of perennating organs called tubers.	True / False
357.	The microsporangia and megsporangia that are borne in specialized structures called sporocarps.	True / False
358.	Sporocarp developed upon short lateral branches.	True / False
359.	Each sporocarp is oval shaped structure attached to the petiole through a small stalk called peduncle.	True / False
360.	The young sporocarps are relatively soft and green, but they become hard, brown, and nut-like at maturity.	True / False
361.	The sporocarps protect the spores until the next dry season.	True / False
362.	A mature sporocarp is surrounded by a thick and rigid three-layered wall consisting of the epidermis containing stomata, the hypodermis composed cells containing chloroplasts and inner wall.	True / False
363.	Both micro- and megasporangia develop in each sorus on a ridge-like receptacle. A row of megasporangia develop at the tip and many microsporangia on the sides of this receptacle.	True / False
364.	In Marselia the megasporangium contains a single large megaspore while the microsporangium contains 32-64 microspores.	True / False

GYMNOSPERMS

365.	One of the most important extinct gymnosperms is the group named seed ferns or Cycadofilicales.	True / False
366.	The living gymnosperms comprise of about 50 genera and 725 species.	True / False
367.	The gymnosperms are heterosporous.	True / False
368.	The sporangia are borne on sporophylls. The sporophylls bearing microsporangia are called microsporophylls whereas those bearing megasporangia or ovules are known as megasporophylls.	True / False
369.	The strobili bearing microsporophylls are called microsporangiate or female strobili.	True / False
370.	Resins are plant exudates secreted in specialized canals or ducts.	True / False
371.	The major source of resins are conifers.	True / False
372.	Wood pulp of some species such as Picea smithiana, Pinus roxburghii, Abies pindrow,etc is used in paper making.	True / False
373.	Most of the newspaper is made from cycas pulp.	True / False
374.	The Cycadophyta include both extinct and living gymnosperms with fern-like foliage.	True / False
375.	Cycas were a flourishing group of plants during cenozoic period but many of the members become extinct and now this group is represented by only nine living genera.	True / False
376.	Cycas leaves show circinate vernation in all condition.	True / False
377.	Cycas is a heterosporous gametophyte.	True / False
378.	The Cycas stem is covered with tough leaf bases.	True / False
379.	Cycas leaves are pinnately compound and exhibit circinate vernation.	True / False
380.	Cycas is dioecious, i.e., male and female plants are separate.	True / False
381.	The male cones of Cycas are largest among the male cones in gymnosperms.	True / False
382.	In Cycas usually a single, woody, spindle-shaped male cone about 100 cm in length develops at the apex of the leaf.	True / False

383.	Each cone comprises of a central axis to which spirally arranged woody microsporophylls are attached.	True / False
384.	Several hundred microsporangia are borne on the abaxial surface of the microsporophyll.	True / False
385.	In Cycas, the megasporophylls are not organized into a cone.	True / False
386.	The female cone consists of compactly arranged megasporophylls which surround the shoot apex like the foliage leaves.	True / False
387.	In Cycas ovules are naked and about 6-8 ovules are arranged laterally on the stipe.	True / False
388.	The ovules are hairy, black in colour and may reach 6 cm in length.	True / False
389.	The Cycas like extinct plants retain fern-like leaves that bore seeds on the leaves.	True / False
390.	The female sporophylls of Cycas which form a loose crown like the male sporophylls of Bennettitales.	True / False
391.	The seed ferns resemble Cycas in structure of their ovule.	True / False
392.	The ovules in cycas possess 2-layered integument.	True / False
393.	The sperms are multiflagellatean motile both in Cycas and primitive plants.	True / False
394.	The large out put of microsopore from microsporaniga as retain by cycas is also a primitive character.	True / False
395.	Coniferales having about 540 species belonging to 20 different genera.	True / False
396.	The member of conifers form the major part of world forests.	True / False
397.	The Pinus plant is an evergreen sporophyte.	True / False
398.	Scale Leaves are brown in colour and protective in nature.	True / False
399.	Needle leaves are needlelike and develop singly or in groups at the apices of long shoots called spurs.	True / False
400.	A mature microsporangium consist of four layered sporangium wall surrounding a mass of microspore mother cells.	True / False
401.	In Pinus female cone consists of an axis upon which a series of appendages called bract scales is arranged.	True / False
402.	In Pinus five ovules are borne on the upper surface near the base of the of ovuliferous scale.	True / False
403.	Pinus exhibits cleavage polyembryony, i.e., cells of proembryo develop independent of each other to 4-8 separate embryos.	True / False

404.	A mature embryo consists of a whorl of cotyledons.	True / False
405.	Ephedra, Gnetum and Welwitschia are the three representatives of this Gnetophyta.	True / False
406.	The members of Gnetophyta are thought to represent a connecting link between the gymnosperms and algae.	True / False
407.	The compound nature of Pinus both male and female strobili considered similar to the inflorescence of angiosperms.	True / False
408.	Ephedra, also commonly known as joint fir, is usually a profusely branched shrub comprising of about 40 species.	True / False
409.	Ephedra gerardiana is found along Himalayas at an altitude of about 3050 meters.	True / False
410	Ephedra intermedia is a common inhabitant of Lahore.	True / False
411.	Sunken stomata are present in the furrows of Ephedra.	True / False
412.	Secondary growth is by the activity of cambium absent in Ephedra.	True / False
413.	Because of superficial resemblance of the reproductive structures of Ephedra to those of angiosperms, these are sometimes referred to as inflorescences or flowers.	True / False
414.	In Ephedra a young ovule consists of a well-developed nucellus enveloped by a fleshy cup-like structure, usually referred to as outer integument; and an inner delicate inner integument.	True / False
415.	The extracts from the roots and stems of Ephedra are used to cure genito-urinary diseases, and as a cooling beverage.	True / False

THE ANGIOSPERMS

416.	An angiospermic plant consists of vegetative organs: the root, stem, branches and leaves; and reproductive organs: the flowers.	True / False
417.	The angiospermic plant is haploid (n) and a sporophyte.	True / False
418.	Each flower consists of 2 types of floral leaves.	True / False
419.	The sepals and petals are together termed perianth.	True / False
420.	In Angiosperms each microspore is unicellular, uninucleate structure possessing 3 layered wall.	True / False
421.	Each megasporophyll or carpel consists of a basal swollen part, the ovary; a stalk usually present at the top of the ovary, the style; and stigma, the variously modified tip of the style.	True / False
422.	The stigma is the receptive disc and receive pollen grains.	True / False
423.	The ovary contains one or more rounded or oval bodies, the ovules.	True / False
424.	The ovules are borne on the ovary wall upon a specialized tissue, the recepticals.	True / False
425.	The microspore is the first cell of the male gametophyte.	True / False
426.	Fertilization in angiosperms is triple fertilization.	True / False
427.	The embryo in dicots is octant type and comprises of an embryonal axis to which the cotyledons are attached.	True / False
428.	In monocots the embryo is tetra type.	True / False
429.	A seed is a ripened ovule protected by seed coat enclosing embryo provided with store food either in endosperms or perisperm.	True / False
430.	The ripened ovary is called as fruit. In angiosperms the seeds are enclosed in the fruit.	True / False
431.	The seed germinate to gametophyte on germination to a suitable place.	True / False

ANSWERS

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MULTIPLE CHOICE QUESTIONS

PLANT DIVERSITY

Algae, Bryophyta, Pteridophyta, Gymnosperms and Angiosperms

Multiple Choice Questions

Please Encircle the Appropriate Letter (a, b, c or d) of the Correct Answer

1 Myxophyta is known as

a) Cyanophyta
b) algae
c) Bacteriophyta
d) Chromatophyta

2. Cyanobacteria is called as blue green algae due to the pigment

a) Chlorophyll
b) phycocyanin
c) diatomin
d) all of these

3. The following is found in the roots of cycads

a) Nostoc
b) Anabaena
c) Spirogyra
d) Oscillatoria

4 Sexual reproduction is absent in

a) Cyanophyta
b) chlorophyta
c) Diatoms
d) Red algae

5 The best pollution indicator alga is

a) Oscillatoria
b) Chara
c) Nitella
d) Spirogyra

6 Akinete is the type of reproduction

a) vegetative
b) asexual
c) sexual
d) non of these

7 Necridia formation is the characteristic of

a) Laminaria
b) Fucus
c) Oscillatoria
d) Nitella

8. About ______ species of algae are used as source of food

a) 100
b) 200
c) 300
d) 400

9. Agar is the product of

a) Gelidium
b) Hypnea
c) Phyllophora
d) All of these

10. The derivative of alginic acid is

Agar agar
b) alginates
c) Iodine
d) Creams

11. Carrageenin is a carbohydrate is obtained from

a) Red algae
b) brown algae
c) golden brown algae
d) green algae

12. Fuscus yield

a) Iodine
b) Carotene
c) agar
d) all of these

13. The presence of oil deposit in the earth crust may by indicated by the presence of fossils of

a) fungi
b) diatoms
c) bacteria
d) red algae

14. The Calvin cycle is best studied in the algae

a) Chlorella
b) Nostoc
c) Chara
d) Laminaria

15 The calcium deficiency in the field can over come the addition of algae

a) Phyllophora b) Chara

c) Chalamodonas d) Euglena

16. The best source of minerals is

a) Kelps b) Brown algae

c) chlorophyceae d) all of these

17 Nostoc and Anabaena is used for

Fertilizers a)

b) land reclamation

c) pollution indicator

d) oil indicators

18. Growth of algae ———— make unfit water for drinking for cattle's

a) Chlorella b) Oscillatoria

c) both a& b d) non of these

19. Lyngbya is act as respiratory disorders in

a) Cattles b) birds

c) human d) all of these

20. The Oscillatoria is the best for

a) Pollution indicator

b) Source of minerals

c) source of medicine

d) skin diseases

21. The number of genera in chlorophyta are

a) 400 b) 450

c) 500 d) 550

22. The cup shaped chloroplast is found in

a) Chlamydomonas

b) Spirogyra

c) Volvox

d) Tetraspora

23 Hormogon formation is common in

a) Nostoc b) Ulothrix

c) Oedogonium d) Dictyota

24. Eye spot in algae is for

a) Color detection

b) Light detection

c) Focus the individual

d) all of these

25. The best example of division of labor in any individual is

Volvox b) Euglena

c) Ectocarpous d) Zygnema

26. Daughter colony formation is the characteristic of

a) Anabaena

b) Stigeoclonium

c) Volvox

d) Pithophora

27. The fusion of similar gametes is termed as

a) Isogamy b) anisogamy

c) Oogamy d) non of these

28. Advanced type of fusion of gametes is

a) Isogamy b) anisogamy

c) Oogamy d) non of these

29. The spiral shaped chloroplast is found in

a) Spirogyra b) Oedogonium

c) Pithophora d) Rivularia

30. The presence of pyrenoid indicate that the reserve food material in algae is

a) Glucose b) starch

c) oil drops d) both a& b

31. The members of chlorophyta are closely related to

a) fungi b) bacteria

c) mosses d) higher plants

32. The type of conjugation found in spirogyra is

a) Lateral b) sclariform

c) horizontal d) both a&b

33. Chara is known as
a) Stone wort b) horn wort
c) chara wort d) all of these

34. The Carophyceae is separated from green algae due to
a) sex organs
b) sterile covering around sex organs
c) multicellular thallus
d) formation of bulbils

35. Amylum stars is the characteristics of
a) Chara b) Spirogyra
c) Pinnularia d) Cosmarium

36. Asexual reproduction is absent in
a) Cyanophyta b) chlorophyta
c) charophyta d) Phaeophyta

37. Star shaped chloroplast is found in
a) Zygnema b) Nitella
c) Coleochaete d) Cladophora

38. Male and female fructification are the sex organs of
a) Diatoms b) Chara
c) Nitella d) both b&c

39. In Vaucheria the reserve food material is
a) Starch b) Oil drops
c) glucose d) all of these

40. The coenocytic plant body is
a) uninucleated b) binucleated
c) multinucleated d) having no nucleus

41. The members of diatoms are rich source of
a) minerals b) vitamin A&D
c) calcium d) non of these

42. Corel reaf are formed by the deposition of corals and
a) diatoms b) petroleum
c) Laminaria d) Polysiphonia

43. Laminate chloroplast is found in
a) Botrydium b) Vaucheria
c) Pinnularia d) Euglena

44. Fucoxanthin imparts the color to algae
a) Brown b) green
c) Red d) blue

45. Kelps belongs to
a) Red algae b) brown algae
c) Green algae d) golden brown algae

46. The best example of isomorphic alternation of generation is
a) Ectocarpous b) Laminaria
c) Funaria d) all of these

47. Carpospores and monospores are found in
a) green algae b) red algae
c) diatoms d) blue green algae

48. Motile reproductive bodies even the motile male gamete are absent in
a) Cyanophyta b) chlorophyta
c) Phaeophyta d) Rhodophyta

49. Siphonaceous thallus is found in
a) Batrachospermum
b) Polysiphonia
c) Floridae
d) all of these

50. Manitol is reserve food in
a) Cladophora b) Cosmarium
c) Pleurococcus d) Laminaria

51. Epitheca and hypo theca is the characteristics of
a) Pinnularia b) Diatoms
c) Botrydium d) all of these

52. The cell wall of diatoms is made up of
a) cellulose b) pectin &silica
c) chitin d) both a&b

53 The amphibians of the plants are
a) algae b) fungi
c) bryophytes d)gymnosperms

54. A-tracheophytes are
a) algae b) fungi
c) bryophytes d) all of these

55. The number of genera of bryophytes known so far are
a) 960 b) 1050
c) 1100 d) 1160

56. The tracheophytes are
a) Pteridophytes
b) gymnosperms
c) angiosperms
d) all of these

57 The number of species of bryophytes are
a) 2200 b) 2400
c) 2600 d) 2800

58 The principle phase in bryophyte is
a) gametophyte b) sporophyte
c) both a&b d) non of these

59. In bryophyte the sporophyte is
a) independent
b) dependent to gametophte
c) partially independent
d) non of these

60 In bryophyte the sporophyte depend upon gametophyte for
a) food b) attachment
c) both a&b d) non of these

61 Peat is the partially decay of
a) algae b) fungi
c) moss d) all of these

62 Medicine obtained from Polytrichum is used as
a) anti cancer
b) dissolve stone
c) antibiotics
d) anti fungal

63. In bryophytes the source of food for human is
a) Funaria b) Sphagnum
c) Riccia d) Bryum

64. Hepatophytes are commonly known as
a) Liver worts b) Mosses
c) peat moss d) non of these

65. Gemma formation is the characteristics of
a) Marchantia b) Riccia
c) Pellia d) Anthoceros

66. Tuber formation is the characteristics of
a) Marchantia b) Riccia
c) Pellia d) Anthoceros

67. Rosette like structure is formed by
a) Riccia b) Pellia
c) Funaria
d) Sphaerocarpous

68. Porella belongs to order
a) Marchantiales
b) Jungermenales
c) Funariales
d) non of these

69. Foot and seta is absent in the sporophyte of
a) Riccia b) Porella
c) Anthoceros d) All of these

70. Amphigastria is the found in
a) Riccia b) Porella
c) Anthoceros d) All of these

71. Porella is known as
a) Liverworts
b) Leafy liverworts
c) stone worts
d) moss

72. Perianth and involucer if found in the sporophyte of
a) Marchantia b) Porella
c) Pellia d) Riccia

73 Umbrella like sex organs are found in
a) Marchantia b) Anthoceros
c) Pellia d) Riccia

74. Anthoceros is known as
a) Peat moss b) liverworts
c) horn worts d) both b&c

75. Meristematic tissues are found in the sporophyte of
a) Marchantia b) Anthoceros
c) Funaria d) Riccia

76. The leaves of bryopsida is not true leaves because
a) non vascular tissues
b) no sex organs
c) non photosynthetic
d) all of these

77 The non-vascular land plants are included in the group called
a) Thallophyta b) Bryophyta
c) Tracheophyta d) Pteridophyta

78. Xylem and Phloem are found only in vascular land plants which belong to the group
a) Thallophyta b) Bryophyta
c) Tracheophyta d) Pteridophyta

79. Because of their dependence on water, bryophytes are sometimes called
a) Tracheophytous b) Bryophytous
c) Amphibious d) None of the above

80 In bryophytes male sex organ is known as
a) Archegonium b) Antheridium
c) Sporangium d) Oogamy

81. In bryophytes female sex organ is known as
a) Archegonium b) Antheridium
c) Sporangium d) Zooids

82. In bryophytes the structure which are equivalent to the roots of vascular plants are the
a) Antheridia b) Rhizoids
c) Zooids c) Archegonia

83. The cuticle of most of the bryophytes is made up of
a) Cutin b) Wax
c) Lignin d) Chitin

84. The unique feature of bryophytes compared to other green plants groups is that
a) they lack roots
b) they lack vascular tissue
c) they produce spores
d) their sporophytes is attached to gametophyte

85 Positive evidence of the aquatic ancestry of bryophytes is
a) Protonema
b) Green colour
c) Ciliated sperm
d) Some forms are purely aquatic

86. Bryophytes are popularly called amphibians of the plants kingdom because
a) they grown on land
b) they are aquatic
c) they grow on damp soil and require water to carry out sexual reproduction
d) all of these

87. Moss capsule represents
a) sporophyte
b) a part of sorus
c) gametophyte
d) all of the above

88. On germination a moss spore forms
a) protonema which bears sex organs
b) sex organs

c) protonema which gives rise to buds that grow into new moss
d) moss plant directly

89. The spore producing organ in bryophytes are
a) Foot b) seta
c) capsule d) antheridia

90. The production of sporophyte directly from, gametophyte without syngamy is called
a) Apogamy b) apospory
c) Fertilization d) non of these

91 The haploid gamete producing generation is called as
a) sporophyte b) gametophyte
c) adult d) all of these

92. The production of only one kind of spores is termed as
a) homospory b) heterospory
c) apospory d) autospory

93. Which one is not the character of bryophytes?
a) presence of archegonia
b) independent sporophyte
c) motile germs
d) water is essential for fertilization

94. Gametophytic generation is dominant in
a) Bryophytes b) pteridophytes
c) gymnosperms d) angiosperms

95. A bryophytes is differ from pteridophytes because
a) Archegonia
b) lack vascular tissue
c) motile gametes
d) independent gametophyte

96. The simplest sporophyte is found in
a) Marchantia b) Riccia
c) Anthoceros d) Funaria

97. In which of the following plant the sporophyte is completely depend on gametophyte
a) Riccia b) Pteris
c) Marselia d) Brassica

98. Which of the following is absent in moss sporophyte
a) Foot b) seta
c) capsule d) elaters

99. Elongated sporangium is found in
a) Anthoceros b) Funaria
c) Polytrichum d) non of these

100. Peristomes are present in
a) Anthoceros b) Funaria
c) Marchantia d) non of these

101. Polytrichum is also known as
a) Peat moss b) spike moss
c) hair cap moss d) reindeer moss

102. Columella is the part of
a) Foot b) seta
c) capsule d) rhizome

103. Which of the following is fossil bryophyte
a) Riccia b) Marchantia
c) Naiadita d) Funaria

104. The capsule of Polytrichum is divided into
a) Apophysis b) Theca
c) Operculum d) All of these

105. The calyptras in Funaria is like a
a) Cap b) Teeth
c) Oval shape d) all of these

106. The inverted cup like foot is present in
a) Riccia b) Funaria
c) Anthoceros d) Sphagnum

107. The bryophytes are originated from
a) Algae b) fungi
c) Lichens d) angiosperms

108. The archegonia in bryophytes consists of
a) neck & venter b) foot & seta
c) seta & capsule d) non of these

109. The bryophytes spreads on the earth from
a) 450 million years ago
b) 470 million years ago
c) 500 million years ago
d) 520 million years ago

110. The most common moss found in Pakistan is
a) Funaria b) Polytrichum
c) Peat moss d) Bog moss

111. The remains of plant and animals on the earth crust is called as
a) Fossils b) Imprints
c) Impressions d) Coal

112. The best type of fossils are
a) dead and preserved bodies
b) coal
c) petrified fossils
d) impressions

113. Which one of the following is not fossils
a) Petroleum
b) Diatomaceous earth
c) Peat
d) Encrustations

114. Which one of the following is fossil pteridophyte
a) Rhynia b) Lycopodium
c) Psilotum d) Selaginella

115. Protostele is present in
a) Equisetum b) Lycopodium
c) Psilotum d) Selaginella

116. Psilotum consists of
a) Root and Stem
b) Root and leaves
c) Stem and Leaves
d) Rhizome and aerial stem

117. The common characters shared by Rhynia and Psilotum is
a) Photsynthetic stem
b) Leaves
c) Rhizoids
d) Sporangia

118. Spore producing organ of Psilotum is
a) Cone b) Sporangium
c) Synangium d) sorus

119. The leaves of Psilotum are
a) Scale like b) branched
c) photosynthetic d) all of these

120. The prothallus of Psilotum is
a) Photosynthetic b) saprophytic
c) parasitic d) non of these

121. The gametophyte of Psilotum is infested with
a) Algae b) fungi
c) both a&b d) non of these

122. The Selaginella is
a) Homosporous
b) heterosporous
c) bisporous
d) non of these

123. Heterospory leads to evolution of
a) Seed formation
b) flower formation
c) fruit formation d) all of these

124. Spore producing organ of Selaginella is
a) Cone b) Sporangium
c) Synangium d) sorus

125. The tong like out growth at the base of leaf is
a) ligule b) scale
c) stipule d) non of these

126. In Selaginella ligule is present at the base of
a) rhizome b) stem
c) leaf d) all of theses

127. The stele of Selaginella is
a) protostele b) dictyostele
c) solenostele d) siphonostele

128 Selaginella is the member of
a) Eligulopsida b) ligulopsida
c) Calamopsida d) non of these

129. In Selaginella the male gametes are
a) A flagellated
b) uniflagellated
c) biflagellate
d) multiflagellated

130. Endodermis is trabiculated in
a) Selaginella b) Equisetum
c) Marselia d) all of these

131. In Selaginella the stem is
a) herbaceous and branched
b) herbaceous and unbranched
c) woody
d) none of above

132. In Selaginella the leaves are
a) homo b) hetero
c) both a&b d) non of these

133. The sporangia of Selaginella is
a) homosporous
b) heterosporous
c) absent
d) non of these

134. Reduction division in life cycle of Selaginella occur in
a) Germination of zygote
b) formation of spores
c) germination of spores
d) both during germination of zygote and spore

135. Selaginella is also called as
a) Club moss b) horse tail
c) water fern d) non of these

136. Equisetum is also called as
a) Club moss b) horse tail
c) water fern d) non of these

137. The spores with elaters are found in
a) Equisetum b) Adiantum
c) Lycopodium d) Marselia

138. Vallecular canal and carinal cavities are found in
a) Equisetum b) Adiantum
c) Lycopodium d) Marselia

139. In Equisetum the vallecular canal is present in stem below
a) Ridges
b) furrows
c) between the ridges and furrows
d) non of these

140. In Equisetum carinal cavities are present in
a) epidermis b) cortex
c) endodermis d) xylem

141. The stem if Equisetum is
a) smooth
b) having ridges and furrows
c) solid
d) fistular

142. T-shaped peltate appendages called sporangiphore is present in
a) Equisetum b) Adiantum
c) Lycopodium d) Marselia

143. When the vascular bundles are arranged in a ring around a pith such stele is called
a) Solid stele b) protostele
c) actinostele d) siphonostele

144. The name of Equisetum as horse tail is due to
a) branches pattern
b) sporangia
c) fertile branch with sporangia
d) all of these

145. Pteropsida is broadly termed as
a) Pteridophytes b) ferns
c) moss d) non of these

146. Median hair fern is
a) Driopterous b) Adiantum
c) Lycopodium d) Marselia

147. False indusium around sori is found in
a) Equisetum b) Adiantum
c) Lycopodium d) Marselia

148. The leave of Adiantum is
a) single leaf
b) pinnate leaf
c) pinnate and bipinnate leaf
d) non of these

149. The prothallus of Adiantum is
a) dichotomously branched
b) pear shaped
c) heart shaped
d) saprophytic

150 Polypodiaceae contain the member
a) Adiantum b) Polypodium
c) Equisetum d) both a&b

151. The water fern is
a) Equisetum b) Adiantum
c) Lycopodium d) Marselia

152. The cruciform leaf are present in
a) Marselia b) Adiantum
c) Selaginella d) both a&b

153. Aerenchyma in stem is present in
a) Marselia b) Polypodium
c) Selaginella d) non of these

154. In Marselia stem the phloem is present
a) outside xylem
b) inside xylem
c) both inside and out side
d) no phloem

155. The sporocarp is found in
a) Marselia b) Adiantum
c) Selaginella d) both a&b

156. Rhizophores are found in
a) Marselia b) Adiantum
c) Selaginella d) both a&b

157. Pteridophytes are
a) non vascular plants
b) vascular plants
c) lower vascular plants
d) non of these

158. Geological time scales tell us
a) life of earth
b) life and history of earth
c) evolution of plants and animals
d) all of these

159. Bacteria, fungi and algae originate in era
a) Pre-Cambrian b) Cambrian
c) Paleozoic d) Cenozoic

160. First plant spore appeared in period
a) Cambrian b) Ordovician
c) Silurian d) Devonian

161. Marine algae dominated in
a) Cambrian b) Ordovician
c) Silurian d) Devonian

162. First known land plant appeared in
a) Cambrian b) Ordovician
c) Silurian d) Devonian

163. Liverworts appeared in
a) Cambrian b) Ordovician
c) Silurian d) Devonian

164. Coal formed in
a) Cambrian
b) Carboniferous
c) Permian
d) Devonian

165 Mosses appeared in
a) Cambrian
b) Carboniferous
c) Permian
d) Devonian

166. Cycads appeared in
a) Triassic
b) Carboniferous
c) Jurassic
d) Cretaceous

167 Flowering plants arose in
a) Triassic b) Carboniferous
c) Jurassic d) Cretaceous

168. Grasses developed in
a) Eocene b) Miocene
c) Pliocene d) Recent

169. The herbs arose during
a) Eocene b) Miocene
c) Pliocene d) Recent

170. Herbs dominated in
a) Eocene b) Miocene
c) Pliocene d) Recent

171. Flowering plants flourish in
a) Triassic b) Carboniferous
c) Jurassic d) Cretaceous

172. Naked seeded plants are
a) Ferns b) Pteridophytes
c) gymnosperms d) angiosperms

173. Cycads includes .
a) extinct genera
b) living genera
c) both extinct and living genera
d) non of these

174. Which one of the following has fern like appearance
a) Cycadophytes b) Ginkgophyta
c) Coniferopsida d) Taxopsida

175. Double fertilization is present in
a) Bryophytes
b) pteridophytes
c) angiosperms
d) gymnosperms

176. Ovule is naked in
a) Bryophytes
b) pteridophytes
c) angiosperms
d) gymnosperms

177. The stele in gymnosperms is
a) Protostele b) eustele
c) actinostele d) all of these

178. Heteromorphic alternation of generation is found in
a) pteridophytes b) angiosperms
c) gymnosperms d) all of these

179. Vegetative reproduction is absent in gymnosperms except
a) Cycas b) Pinus
c) Taxes d) Ephedra

180. Chilghoza belongs to genus
a) Cycas b) Pinus
c) Taxes d) Ephedra

181. Gymnosperms lake true vessels except
a) Cycas b) Pinus
c) Taxes d) Ephedra

182. Coralloid roots are present in
a) Psilotum b) Pinus
c) Cycas d) all of these

183. Bulbils is the type of reproduction
a) vegetative b) asexual
c) sexual d) non of these

184. Bulbils is present in
a) Cycas b) Pinus
c) Taxes d) Ephedra

185. Megasporophyll of Cycas is
a) leaf like

b) pinnate leaf like
c) compact
d) lossely arranged

186 Sago is obtained from
a) Palm b) Cycas
c) Taxes d) Brassica

187 The living fossil is
a) Rhynia b) Psilotum
c) Cycas d) Pinus

188 The largest ovule is found in
a) Cycas b) Pinus
c) Cabbage d) Turnip

189 Resin canal is present in
a) Zamia b) Pinus
c) Taxes d) Ephedra

190 The pollen grain of Pinus is
a) Winged b) small
c) Hard and stony d) non of these

191 Ephedrine is obtained from
a) Zamia b) Ginkgo
c) Ephedra d) Pinus

192 During alternation of generations, a plant alternates between ——————
A) gametophyte and sporophyte
B) diploid and haploid
C) gamete-producer and spore-producer
D) All of these are correct.

193 One of the main criteria used to differentiate between major plant groups is ——————
A) Color
B) type of chlorophyll
C) presence of vascular tissue to transport water and nutrients
D) flower type

194 Plants most likely evolved from what group?
A) freshwater green algae called charophytes
B) red and brown algae
C) Chrysophyta
D) All of these groups gave rise to at least one group of land plants.

195 What trait(s) enabled plants to colonize dry land?
A) lignin reinforcing cell walls
B) vascular tissue
C) waterproof cuticle and stomata
D) All of these are correct.

196 At what point in evolutionary history did the co evolution of flowers and insects become important?
A) at the beginning of the Cambrian
B) during the Devonian period
C) about 90 million years ago
D) recently, around 100,000 years ago

197 The archegonium of a moss produces a(n) ——————.
A) abundant supply of sperm cells
B) Flower
C) Egg D) Spore

198 True or false. Most bryophyte reproduction occurs asexually.
A) True B) False

199 What do bryophytes and ferns require for successful reproduction that other more complex plants do not?
A) high summer temperatures
B) a period of dormancy
C) free water in which sperm can swim to eggs
D) freezing temperatures to activate sperm cells

200 The bryophyte that has a thalloid life form and reproduces asexually by gemmae is the ——
A) Moss B) Liverwort
C) Hornwort
D) All of these are correct

201 How are the cells of hornworts different from the cells of other bryophytes?

A) Interlocking

B) thick-walled

C) one chloroplast per cell

D) All of these are correct

202 Peat moss is economically important because it is a significant ———.

A) source of fertilizer

B) renewable energy source

C) habitat for other organisms

D) Ecosystem

203 How do seedless vascular plants differ from bryophytes?

A) well-developed cuticle

B) vascular tissue

C) different life cycle

D) Both a and b are correct

204 The largest group of seedless vascular plants are the ———

A) true ferns B) horsetails

C) club mosses D) whisk ferns

205 The simplest seedless vascular plants with no true leaves and no roots are the ———

A) true ferns B) Horsetails

C) club mosses D) whisk ferns

206 The spores of a seed-bearing plant can give rise to a ———

A) male gametophyte

B) female gametophyte

C) sporophyte

D) Both a and b are correct.

207 The oldest living tree species is a ———

A) Gingko B) Conifer

C) Gnetophyte D) pine tree

208 True or false. The pine life cycle is so rapid that new seeds are sprouting only three months after pollination.

A) True B) False

209 Angiosperms are the only plants that produce ———.

A) pinnate leaves B) Flowers

C) Sperm D) Seeds

210 The extinction of dinosaurs in the Tertiary period ———.

A) coincided with a great loss of plant diversity

B) led to the rapid evolution of the cycads

C) was followed by an explosion of angiosperm evolution

D) was followed by a distinct increase in gymnosperm populations

211 Fruit is present in

a) Fungi b) Pteridophytes

c) Gymnosperms d) Angiosperms

Algae, Bryophyta, Pteridophyta, Gymnosperms and Angiosperms

ANSWERS

1. a	2. b	3. b	4. a	109. b	110. a	111. a	112. c
5. a	6. b	7. c	8. a	113. c	114. a	115. c	116. d
9. d	10. b	11. a	12. a	117. a	118. c	119. a	120. b
13. b	14. a	15. a	16. a	121. b	122. b	123. a	124. a
17. b	18. c	19. c	20. a	125. a	126. c	127. d	128. b
21. b	22. a	23. a	24. b	129. c	130. a	131. a	132. c
25. a	26. c	27. a	28. c	133. b	134. b	135. a	136. b
29. a	30. b	31. d	32. d	137. a	138. a	139. b	140. d
33. a	34. b	35. a	36. c	141. b	142. a	143. d	144. c
37. a	38. d	39. b	40. c	145. b	146. b	147. b	148. c
41. b	42. a	43. c	44. a	149. c	150. d	151. d	152. a
45. b	46. a	47. b	48. d	153. a	154. c	155. a	156. c
49. b	50. d	51. a	52. b	157. c	158. d	159. a	160. a
53. c	54. d	55. a	56. d	161. b	162. c	163. d	164. b
57. b	58. a	59. c	60. c	165. b	166. a	167. c	168. b
61. c	62. b	63. b	64. a	169. c	170. d	171. d	172. c
65. a	66. b	67. a	68. b	173. c	174. a	175. c	176. d
69. a	70. b	71. b	72. b	177. b	178. d	179. a	180. b
73. a	74. d	75. b	76. a	181. d	182. c	183. a	184. a
77. b	78. c	79. c	80. b	185. b	186. b	187. c	188. a
81. a	82. b	83. a	84. d	189. b	190. a	191. c	192. d
85. c	86. c	87. a	88. c	193. c	194. a	195. c	196. a
89. c	90. a	91. b	92. a	197. c	198. a	199. c	200. b
93. b	94. a	95. b	96. b	201. b	202. d	203. d	204. a
97. a	98. d	99. a	100. b	205. c	206. a	207. b	208. a
101. c	102. c	103. c	104. d	209. b	210. d	211. d	
105. a	106. c	107. a	108. a				

Virus, Bacteria, Fungi

Virus, Bacteria, Fungi

Multiple Choice Questions

1. A slippery outer covering in some bacteria that protects them from phagocytosis by host cells is
   - a. capsule
   - b. cell wall
   - c. flagellum
   - d. peptidoglycan

2. When flagella are distributed all around a bacterial cell, the arrangement is called
   - a. polar
   - b. random
   - c. peritrichous
   - d. encapsulated

3. A shiny, sticky colony of Streptococcus pneumoniae is likely to be
   - a. encapsulated and pathogenic
   - c. nonencapsulated and nonpathogenic
   - b. nonencapsulated and pathogenic
   - d. encapsulated and nonpathogenic

4. A bacterial cell wall does all of the following except
   - a. gives shape and rigidity to the cell
   - b. is the site of action for some antibiotics
   - c. is associated with some symptoms of disease
   - d. protects the cell from phagocytosis

5. The minimum distance at which a microscope is capable of distinguishing two points as separate is its
   - a. magnification
   - b. illumination
   - c. resolving power

6. A Gram negative cell wall is ——— than a Gram positive one.
   - a. thicker
   - b. thinner

7. Because penicillin prevents peptidoglycan synthesis, it is more effective on ——— cells.
   - a. Gram positive
   - b. Gram negative

8. Flagella and pilli are made of
   - a. lipids
   - b. carbohydrates
   - c. nucleic acids
   - d. protein

9. The genetic information of bacteria is stored in ———, in one circular chromosome located in the cytoplasm.
   - a. DNA
   - b. protein
   - c. phospholipids
   - d. RNA

10. Differences between eukaryotic and prokaryotic cells include all of the following except
    - a. eukaryotic cells have mitochondria
    - b. eukaryotic cells have cilia and flagella with complex structure
    - c. prokaryotic cells have more complex cell walls
    - d. prokaryotic cells have no genetic material

11. The fact that viruses are obligate intracellular parasites means that they require a ——— for reproduction.
    - a. culture dish
    - b. host cell
    - c. phenol red broth
    - d. secondary virus

12. One way to determine the size, cell morphology and grouping of bacterial cells is to use a ——— technique.
    - a. streak plate

b. phenol red
c. simple stain
d. nutrient broth culture

13 Cloudiness is a sign that bacteria have grown in a ——— after inoculation and incubation.
a. streak plate
b. tube of nutrient broth
c. Gram stain
d. simple stain

14. The bacterial envelope includes all of the following structures except
a. capsule b. cell wall
c. cell membrane d. endospore

15. All of the following structures of bacteria contain (or are made of) protein except
a. plasmids
b. ribosomes
c. pilli
d. cell membrane

16. Which of the following contains polysaccharide?
a. Gram negative cell wall
b. pilli
c. flagella
d. plasmids

17. Which of the following contains DNA?
a. Gram positive cell wall
b. capsule
c. pilli
d. plasmids

18 In a Gram stain procedure, bacteria with Gram positive cell walls decolorize less easily than those with Gram negative cell walls.
a. true b. false

19. The cell wall type that has less peptidoglycan is
a. Gram negative
b. Gram positive

20 The cell wall type that is most vulnerable to the action of penicillin is
a. Gram negative
b. Gram positive

21. When flagella are located around the entire bacterial cell, the arrangement is called
a. polar b. random
c. bipolar d. peritrichous

22. An encapsulated cell will reproduce to form colonies that appear
a. nonpathogenic b. translucent
c. pink d. smooth

23. Endospore are all of the following except ——— as compared to vegetative cells.
a. more likely to survive treatment with disinfectants
b. more likely to die in nutritionally poor conditions
c. more resistant to staining
d. more resistant to temperature changes

24. Phagocytosis of the bacteria that cause pneumonia is ——— likely if the bacteria are protected by a capsule.
a. less b. more

25. If you use a visible light microscope to examine a live culture of a bacterium possessing flagella, you will be able to see the flagella moving the bacteria.
a. true b. false

26. In what phase of the growth curve is/does a culture (use letters on phases of growth curve for answers):
a. most sensitive to antibiotics? a, B-exponential growth, c, d
b. have the maximum amount of nutrients? A-initial stationary, b, c, d

c have the maximum amount of accumulated waste products?
a. b. c. D-exponential death

d have equal #'s of dividing and dying cells? A-initial stationary.
b. C-maximum stationary. d

27. Most human pathogens prefer temperatures near that of the human body. They are called

a psychrophiles b thermopiles
c mesophiles d. halophytes

28. The optimum temperature for an organism is the one at which

a it grows with the shortest generation time
b it has the longest time between cell divisions
c it is near one extreme of its range of tolerated temperatures
d its enzymes begin to denature

29 The breakdown of glucose to pyruvate is called glycolysis and produces most of the ATP available from the glucose molecule

a true b. false

30. Energy is stored in the ATP (adenosine triphosphate) molecule in its

a sugar portion
b adenine portion
c third phosphate bond

31 Organisms that ferment glucose may produce any of the following end products except

a lactic acid
b propionic acid
c alcohol
d oxygen

32 Viral genes are made of

a RNA only
b DNA only
c. Either DNA or RNA
d. Either protein or nucleic acid

33 A virion is a

a Virus
b Viral ribosome
c. Viral lysosomes d Viral gene

34. An isolated virus is not considered living since it

a. Separates into two part
b. Cannot metabolize
c. Rapidly loses its genome
d. Is coated with air-tight, chemically inert shield

35. Most RNA viruses carry a gene for an enzyme that uses viral RNA as template in the synthesis of more viral RNA this enzyme is

a. Reverse transcriptase
b. RNA polymerase
c. Viral nuclease
d. RNA replicase

36. The enzymes involved in viral replication are synthesized

a. On the viral ribosome
b. By the host cell
c. On the interior surface of the viral membrane
d. On the interior surface of the viral coat

37. Much of the research on gene expression has been done with E.coli, which inhibits the human intestine. This organism is a

a. Plasmid b. Virus
c. Bacterium d. Protozoan

38. In general bacterial genes are regulated at the time of

a. Transcription
b. Post-transcription
c. Translation
d. Conjugation

39. When DNA is exchanged via cytoplasmic bridges between two bacteria the process is called

a. Transduction
b Conjugation
c Transformation
d Recombination

40 When a bacteriophage in its lytic phase carries some of the bacterium's partially digested chromosome with it to another host cell the process is called

a. Conjugation
b Transformation
c Transduction
d Restricted transduction

41. A bacteriophage with a lysogenic cycle must have genes that are

a Made of RNA
b. Made of double-stranded DNA
c. Made of single-stranded RNA or DNA
d With in a circular nucleic acid molecule

42. Which of the following fungus is used to give the flavor, aroma and characteristics colour to some cheese?

a. Yeast b. Ergot fungi
c. Aspergillus d. Penicillium

43 According to mode respiration which one of the following group of bacteria can grow either in the presence or absence of oxygen?

a. Facultative bacteria
b. Microaeerophilic
c. Pseudomonas
d.Spirochete

44 Which one is true for Pox-viruses?

a. RNA-enveloped
b DNA-non enveloped
c DNA-enveloped
d DNA-naked virion

45 A disease virus in which nerves are damaged is the

a. Yellow fever
b. Polio

c. Meas
d Xero

46 In so
occurs
produ
a Str
b sa
c D
d S

47 Gra
a.
c

48. A
h

49.

50.

5

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a. Yellow fever

b. Polio

c. Measles

d. Xerophthalmia

46. In some bacteria when division occurs in random plane it will produce an Arrangement called

a. Streptococcus

b. sarcina

c. Diplococcus

d. Staphylococuus

47 Gram positive bacteria are usually

a. Cocci b. Bacilli

c. Stained pink d. Spirochete

48, A viral disease in which brain of the host is affected is the

a. Sleeping sickness b. Rabies

c. Pellagra d. Typhoid

49. Mumps and measles viruses belong to group paramyxo-viruses which are the

a. RNA enveloped viruses

b. DNA naked viruses

c. RNA non-enveloped

d. DNA enveloped viruses

50. There are about known species of bacteria that causes the diseases in man

a. 250 b. 150

c. 200 d. 300

51. Morphologically the tobacco mosaic virus is the

a. Round shape b. Tadpole like

c. Cubical shape d. Rod shape

52. All of the following is due to bacterial activity except that of

a. Butter milk b. Yogurt

c. Ice cream d. Cheese

53 A scientist who established principles of immunity in "Anthrax &Rabies" was the

a. Leeuwenhoek b. Pasture

c. Koch d. Jenner

54 The poison produced by bacteria during infection in host is called

a Toxins b Antitoxins

c Toxoids d Afflotoxins

55 All of the following are antibiotics, except that of

a Penicillin b. Streptomycin

c Riboflavin d. Terramycin

56. Bacteria ranges in size, whereas, the staphylococcus streptococcus are in diameter

a 0 75 to 1.25 m

b 1.1 to 1.50 m

c. 2.0 to 6.0 m

d. 0.75 to 1.75 m

57. Which one is true for periplasmic space in different groups of bacteria

a. Present in all Gram -negative bacteria

b Present in all Gram positive bacteria

c. Present in few Gram negative bacteria

d. Present in all Gram positive & few gram negative bacteria

58 The amount of lipid in outer boundary of gram positive bacteria is about

a. 1-4 % b 11-12%

c. 8-11% d 20-60%

59, Which one of the following antibiotics &related compounds cause permanent discoloration of teeth in young children

a. Tetracycline b. Terramycin

c. Streptomycin d. Penicillin

60, Antibiotics are synthesized by certain organisms such as

a. Penicillium

b. Actinomycetes

c. Both a & b

d. Oscillatoria

61 Ecological role of fungi as decomposers is paralleled only by

a. Virus b Bacteria

c. Detritus d Nematodes

62. Are very good bio-indicator of air quality as they are very sensitive to pollution

a. Bacteria

b. Mycorrhizae

c. Lichens

d. Water blooms

63. Induction is a process in which a viral DNA

a. Enters into bacterial cell and attached with bacterial DNA

b. Detached from bacterial DNA

c. Destroy the bacterial DNA

d. Multiply with bacterial DNA

64. How many species of fungi are thought to exist?

a). 1500

b). 150,000

c). 1.5 million

d). 1.5 billion

65. Which of the following is not a characteristic of the fungi?

a) They are all absorptive heterotrophs.

b) They have cell walls made of chitin.

c) Mitosis takes place within the nuclear membrane.

d) They are all motile.

66. A mycelium is

a) a specialized reproductive structure of a fungus.

b) a mass of connected fungal hyphae.

c) a mutualistic relationship between a fungus and a plant.

d) a partition between the cells of fungal hyphae.

67 Which of the following statements best describes fungi?
a) All are eukaryotic, multicellular autotrophs.
b) All are eukaryotic heterotrophs that feed by absorption.
c) All are prokaryotic, multicellular autotrophs.
d) All are eukaryotic heterotrophs that feed by ingestion.

68. A wildlife pathologist is examining some skin tissue from a dead frog. She notes the presence of a fungus. She cultures some of the fungal cells and notices that some of the cells are flagellated. She concludes that the frog has a fungal disease caused by
a) an ascomycete.
b) a zygomycete.
c) a basdiomycete.
d) a chytrid.

69. You are walking in the woods and see a fungus that is unfamiliar to you. You remove a reproductive structure, and take it home to examine further. When you look at it under the microscope, you find a zygosporangium. Based on this information alone, this fungus is a(n)
a). zygomycete. b). chytrid.
c). basdiomycete. d). ascomycete.

70. A basidium is typically observed in the common
a). bread mold.
b). gilled mushroom.
c). lichen.
d). chytrid.

71 An ascomycete can be distinguished from other fungi
a) because ascomycetes are mainly diploid.
b) because ascomycetes lack a dikaryotic phase
c) by the presence of eight sexual spores in an ascus
d) by the presence of gills on the mycelium

72 A lichen can be described as a mutualistic symbiosis between an ascomycete and a(n)
a). chytrid
b). archeobacterium
c). green alga.
d). angiosperm root.

73. The study of fungi is called
a. Mycology b. Bryology
c. Phycology d. Taxanomy

74. The study of algae is called as
a. Mycology b. Pathology
c. Phycology d. Taxanomy

75. The study of bryophyte is called as
a. Mycology b. Bryology
c. Phycology d. Embryology

76. Yeast is a fungi
a. Hyphal b. Non hyphal
c. Both a&b d. Non of these

77. yeast has
a. unicellular thallus
b. multicellular thallus
c. non- thallus
d. all of these

78. Fungous means
a. Mushrooms b. develop
c. flourish d. all of these

79. The cell wall of fungi contain
a. chitin b. cellulose
c. non- thallus d. all of these

80. The naked spores are
a. spores b. conidia
c. aplano spores d. zoospores

81. The motile spores are
a. spores b. conidia

82 Aspergillus is a good source of
a amylase b cellulose
c. protease d.non of these

83. Most of the forest are destroyed by
a algae b fungi
c fire d.by man

84 Myxomycota is known as
a water moulds b. fungi
c myxomycota d.oomycetes

85 Rust belongs to
a spores b. conidia
c. aplano d.all of these

86. The fungi imperfecti are
a. zygomycetes
b. ascomycetes
c. basidiomycetes
d. deuteromycetes

87 The spores produce in pod like structure by
a zygomycetes
b ascomycetes
c basidiomycetes
d. deuteromycetes

88. The spores are forcibly discharge in
a zygomycetes
b. ascomycetes
c. basidiomycetes
d. deuteromycetes

89 Fairy rings are produced in
a. Pythium b. Agarics
c. Mucor d.all of these

90 Damping off is caused by
a. Pythium b. Agarics
c. Mucor d.all of these

91 Damping of is the disease of
a seedling b stem
c. leaf d.infloracence

92. Smut is the disease of
a root b. stem
c. leaf d.infloracence

93 Rust is the disease of
a seedling b stem
c leaf d.both b&c

94. Penicillia is commonly known as
a. blue mold b. green mold
c. blue green mold d.all of these

95. Symbiotic association is found in
a. algae b. fungi
c. lichens d bacteria

96. Which one of the following have no benefit known so for
a. fungi b. lichens
c. bacteria d.virus

97. Phyllactinia cause disease
a. powdery mildew b. rust
c. spot d.smut

98. Heteroecious fungus is
a. Agarics b. Puccinia
c. Ustilago d.all of these

99. Rust is caused by
a.virus b. Puccinia
c. Ustilago d.all of these

100. TMV is caused by
a. virus b. bacteria
c. fungi d.all of these

101. Alternaria reproduce by
a. spore b. conidia
c. sexually d.zoospores

102. Cotton wilt is caused by
a. bacteria b. fungi
c. virus d.both a&b

103. Citric acid is produced by fermentation
a. aerobic b. anaerobic
c. alcoholic d.all of these

104 Beneficial bacteria belongs
a. rhizophores b. nodulated
c. azobacter d.all of these

105 About ---------- species of bacteria are known to cause disease in plants
a. 100 b. 200
c. 300 d. 400

106 The heavy metals like Cu can be extracted from water with the help of
a. bacteria b. fungi
c. lichens d. all of these

107 Citrus canker is caused by
a. Xanthomonas
b. Pseudomonas
c. Clostridium
d. both a&b

108 Potato scab is caused by
a. Xanthomonas b. Streptomyces
c. Clostridium d. all of these

109 Leaf blight of rice is caused by
a. Xanthomonas b. Streptomyces
c. Clostridium d. all of these

110 Rust is caused by
a. Ustilago b. Puccinia
c. Pythium d. Phytopthora

111 Late blight of potato is caused by
a. Ustilago b. Puccinia
c. Pythium d. Phytopthora

112 Shelf fungi is a
a. parasitic fungi
b. wood rotting fungi
c. both a&b
d. all of these

113 Dry rot is caused by
a. Serpula b. Candida
c. Phytopthora d. non of these

114 Curd is produced by
a. fungi b. bacteria
c. alcohol d. acid

115 Yogurt can be prepared by the fermentation with
a. fungi b. bacteria
c. both a&b d. Yeat

116. Aflatoxin is produced by
a. Aspergillus b. Yeast
c. Candida d. Trichophyton

117 Club root of cabbage is caused by
a. Candida
b. Plasmodiophora
c. Aspergillus
d. non of these

118. The common bread mold is
a. Mucor b. Aspergillus
c. Rhizopous d. Penicillium

119. The bread is readly infected by
a. Mucor b. Aspergillus
c. Rhizopous d. all of these

120. The bread is decomposed by fungi by producing enzyme
a. Amylase b. Cellulase
c. Lipase d. all of these

121. Ascocarp is produced in the members of
a. Zygomycetes
b. Ascomycetes
c. Basidiomycetes
d. Deuteromycetes

122. Basidiocarp is produced in the members of
a. Zygomycetes
b. Ascomycetes
c. Basidiomycetes
d. Deuteromycetes

123. The common method of reproduction by conidia if found in the members of
a. Zygomycetes
b. Ascomycetes
c. Basidiomycetes
d. Deuteromycetes

124. Perithecium is the fruiting body of
a Zygomycetes
b. Ascomycetes
c Basidiomycetes
d Deuteromycetes

125 Cleistothecium is a fruiting body
a. Closed b. Cup shaped
c. flask shaped d. non of these

126. The edible portion of mushroom is its
a. Fruiting body b. Fairy rings
c. Hyphae d. Ascocarp

127 Leaf spot is caused by
a. Lichens b. Candida
c. Phytopthora d. Alternaria

128. The transfer of genetic material from one bacterium to another bacterium through third party is
a. Transduction b. Conjugation
c Transformation d. non of these

129. The rapid growth of bacteria is found in
a lag phase b. log phase
c. stationary phase d. death phase

130. The bacterial growth is sharply decrease in
a lag phase b. log phase
c stationary phase d. death phase

131. The bacteria establish themselves with the environment in
a. lag phase b. log phase
c. stationary phase d. death phase

132. The bacteria can by counted in the lab by its growth on
a. water b. soil
c. agar medium d. all of these

133. Monoculture is a
a. pure culture b. mixed culture
c. growth culture d. non of these

134 The fungi and bacteria can be isolated by
a. pure culture b. mixed culture
c. water culture d. soil culture

135. Different grades of fungi can be seen after its growth on agar medium by
a. pour plate method
b. serial dilution method
c. both a & b
d. non of these

136. The best method of preventing disease of the plant is by
a. Genetic engineering
b. By fungicide
c. Host eradication
d. Temperature treatment

137. Para sexuality is found in the members of
a. Zygomycetes
b. Ascomycetes
c. Basidiomycetes
d. Deuteromycetes

138. Gram staining was developed by
a. Pasteur b. Dutch Gram
c.Danish Gram d.Brown

139. Gram staining is the example of
a. Acid fast stain b. acid stain
c. differential stain d. non of these

140. Gram staining was developed in
a. 1880 b. 1883
c. 1886 d. 1889

141. Counter stain in Gram staining is
a. Safranine b. crystal violet.
c. iodine d. non of these

142. In Gram staining alcohol act on
a. Polysaccharide
b. lipid membrane
c. periplasm
d. bacterial membrane

ANSWERS

1. a	2. c	3. a	4. b	73. a	74. c	75. b	76. b
5. c	6. b	7. a	8. d	77. a	78. c	79. d	80. b
9. a	10. d	11. b	12. c	81. d	82. a	83. b	84. c
13. b	14. d	15. a	16. a	85. a	86. d	87. b	88. c
17. d	18. a	19. a	20. b	89. b	90. a	91. a	92. d
21. d	22. d	23. b	24. a	93. d	94. c	95. c	96. d
25. b	26. b	27. c	28. a	97. a	98. b	99. b	100. a
29. b	30. c	31. d	32. c	101. b	102. d	103. a	104. d
33. a	34. b	35. d	36. b	105. b	106. a	107. d	108. b
37. c	38. a	39. b	40. c	109. a	110. b	111. d	112. c
41. c	42. c	43. a	44. c	113. a	114. b	115. d	116. a
45. b	46. b	47. b	48. a	117. b	118. c	119. d	120. a
49. a	50. a	51. d	52. c	121. b	122. c	123. d	124. b
53. b	54. a	55. c	56. a	125. a	126. a	127. d	128. a
57. a	58. b	59. a	60. c	129. b	130. d	131. a	132. c
61. b	62. c	63. a	64. c	133. a	134. a	135. b	136. a
65. d	66. b	67. b	68. d	137. d	138. c	139. c	140. b
69. a	70. b	71. c	72. c	141. a	142. b		

Caravan's Books and Manuals

In writing this laboratory manual I was conscious of the profound changes that have taken place in the Curriculum of Botany by Higher Education Commission (HEC), at national level. Recently different courses of Botany have been revised and updated at both graduate and postgraduate levels to cater the needs of future trends. The combination of workable experiments with detailed experiment background and operational information will enhance student's interest in the laboratory and enable them to perform effectively and with confidence. A thorough descriptions of the laboratory operations have been given so that the students can begin their experiments after knowing what they are to observe and how to direct their experiment to a successful conclusion. We believe that the approach we are using is new in many respects and envisage that the manual will be of immense help to the students of Botany at graduate level. The manual is quite up to the mark, provides latest approach and is true to the standard of graduate level examinations. The language is very simple, easy and to the point. No unnecessary details have been given. Also, at the end most important questions with answers usually asked by the examiners are given which will be helpful in the students in prepare themselves for viva voce.

Botany

1	Diversity of Plants (Paper A)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
2	Plant Systematics, Anatomy & Development (Paper B)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
3	Cell Biology, Genetics & Evolution (Paper C)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
4	Plant Physiology & Ecology (Paper D)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
5	Botany Laboratory Manual (Paper A)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
6	Botany Laboratory Manual (Paper B)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
7	Botany Laboratory Manual (Paper C)	Tanweer Ahmad Malik, Dr. Hammad Ashraf
8	Botany Laboratory Manual (Paper D)	Tanweer Ahmad Malik, Dr. Hammad Ashraf

Chemistry

1	A Textbook of Organic Chemistry	Dr. K. M. Ibne Rasa, Dr. Abdur Rahman
2	Organic Chemistry objective	Dr. Abdur Rehman
3	A Textbook of Physical Chemistry	Dr. Haq Nawaz Bhatti
4	Experimental Physical Chemistry	Dr. Haq Nawaz Bhatti, Dr. Zahoor H. Farooqi
5	Test Your Chemistry	Dr. Haq Nawaz Bhatti
6	Modern Physical Chemistry	Dr. Haq Nawaz Bhatti, Dr. Zahoor H. Farooqi
7	Physical Chemistry objective	Dr. Haq Nawaz Bhatti
8	Advanced Organic Chemistry	Dr. Haq Nawaz Bhatti
9	A Textbook of Inorganic & Applied Chemistry	Dr. Haq Nawaz Bhatti
10	Laboratory Manual Organic Chemistry	Dr. Abdur Rahman, Dr. Haq Nawaz Bhatti
11	Laboratory Manual Inorganic Chemistry	Dr. Haq Nawaz Bhatti, Rabia Rehman
12	Laboratory Manual Physical Chemistry	Dr. Haq Nawaz Bhatti, Dr. Zahoor H. Farooqi
13	Solution Manual of Organic Chemistry	Dr. Abdur Rehman
14	Spectroscopy and Chemical Analysis	Dr. Abdur Rehman

Physics

1	Mechanics, Waves & Oscillations (Paper A)	Dr. Zahid Farooq
2	Electricity, Magnetism & Thermodynamics (Paper B)	Dr. Zahid Farooq
3	Basic Electronics & Modern Physics (Paper C)	Dr. Zahid Farooq

Zoology

1	Principles of Animal Biology	Khan Muhammad Rafique
2	Principles of Invertebrates Zoology	Khan M. Rafique, Maqbool Ahmad
3	Principles of Chordate Anatomy	Khan M. Rafique, Maqbool Ahmad
4	Principles of Animal Life Objective Paper A	Maqbool Ahmad, Saeed Tahir
5	Animal Diversity Objective Paper B	Maqbool Ahmad, Saeed Tahir
6	Animal Form and Function Objective Paper C	Maqbool Ahmad, Saeed Tahir
7	Laboratory Manual Paper A B & C	Maqbool Ahmad, Saeed Tahir
8	Fundamentals of Zoology for BS Vol. I & II	Maqbool Ahmad, Saeed Tahir
9	NTS Zoology (For GRE & other Test)	Maqbool Ahmad, Saeed Tahir

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